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HYDRAULIC PROPULSION.

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I.

So much has been said and written on the subject of hydraulic propulsion, and the principles underlying it are so well understood, that the author proposes, notwithstanding the title of the paper, to give little more than a description of the latest boat propelled by this system, and a comparison of it with a sister-boat driven by a screw, and with some hydraulic vessels built previously.

The first mention of this system of propulsion which the author is able to find is in an old patent taken out in the year 1661 by Toogood and Hayes, for "a particuler way of Forceing Water through the Bottome or Sides of Shipps belowe the Surface or Toppe of the Water, which may bee of singuler Vse and ease in navigacon." Many patents were subsequently obtained, and Mr. Ruthven, whose patent is dated 1839, built two vessels, one vessel 9 feet long, which was tried in Edinburgh, and the other 40 feet long tried on the Forth in 1844. A vessel for commercial purposes, fitted with Ruthven's propeller was built in Prussia in 1853; and, besides others, a floating fire-engine was constructed on the Thames, in which, by the advice of the late I. K. Brunel, the pumping power was utilized for propelling the vessel, an adaptation of the turbine propeller for which it is specially suited.

Public attention was first prominently directed to the claims of this propeller by the trial of the "Nautilus" in 1866. This vessel, which was 115 feet long, and had engines of 127 indicated H. P., attained a speed of 8.32 knots per hour. She was propelled by a turbine 7 feet in diameter, which drew water from an opening in the bottom of the boat near the fore part, and discharged it through two nozzles in the sides, just, above the water. The area of each nozzle was 78.54 square inches.

In 1866 also the "Waterwitch," an armored gunboat, 162 feet long, 32 feet beam, and having 1,161 tons displacement, was built for the Admiralty at the Thames Ironworks, the machinery being designed by Ruthven, and constructed by Messrs. Dudgeon at Millwall. She was driven by two water-jets, discharged from nozzles at the sides level with the water, the mean diameter of each of which was 24 inches. The speed attained by the vessel was 9.3 knots per hour. This ship was sister to the "Viper," a twin screw-ship, but the latter suffered from the disadvantage of a double keel aft and a slightly fuller run. A detailed comparison between the two will be found in Table 1.

In 1878, a hydraulic torpedo vessel was built by the Swedish Government for

TABLE 1.

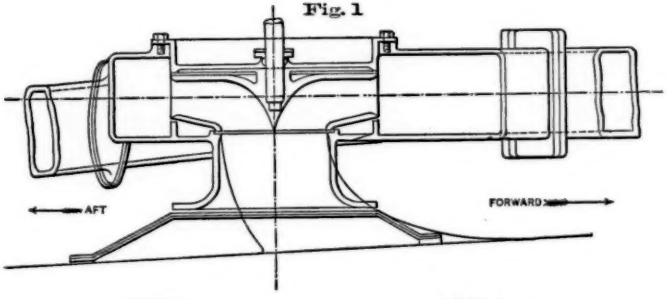
	Date.	Length.	Beam.	Maximum Draught.	Displacement.	I. H. P.	Speed per Hour	Midship Section.	$\frac{V^3 \times D^2_3}{I.H.P.}$	Number of Propellers.	Revolutions per Minute.
		Ft. Ins.	Ft. Ins.	Ft. Ins.	Tons.		Knots.	Sq. ft.			
H. M. S. Viper	1867	162 0	32 0	11 10	1,180.00	696	9.58	337.0	141.4	2 screws.	110
H. M. S. Waterwitch	1867	162 0	32 0	11 2	1,161.00	760	9.30	336.0	116.9	1 turbine.	40
Swedish screw	1878	58 0	10 9	4 3	20.00	90	10.00	25.0	82.0	2 screws.	250
Swedish hydraulic	1878	58 0	10 9	4 2	21.00	78	8.12	25.0	52.5	2 turbines.	384
Thornycroft screw	1883	63 0	7 6	3 8½	12.89	170	17.30	11.9	169.0	1 screw.	636
Thornycroft hydraulic	1883	66 4	7 6	2 6	14.40	167	12.60	13.4	72.0	1 turbine.	428

TABLE 2.

	Diameter of Turbine.	Area of Inlet.	Combined Area of Discharge.	$\frac{\text{Midship section}}{\text{Area of Discharge.}}$	Velocity of Discharge.	Water Discharged.	Efficiency of Pumps and Jet.	Total Efficiency.
	Feet Ins.	Square feet.	Square feet.		Feet per sec.	Lbs. per sec.		
H. M. S. Waterwitch	14 0	28.25	6.280	53 5	29.0	11,650	0.234	0.180
Swedish hydraulic	1 11½	1.62	0.864	30.5	28.0	1,510	0.277	0.214
Thornycroft hydraulic	2 6	1.52	0.951	14.1	37.2	2,210	0.330	0.254

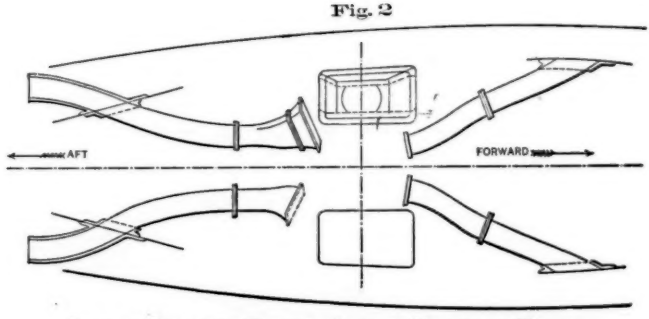
competition with a similar vessel with twin screws; and by the kindness of her designer, Mr. Lilliehook, the author is able to give drawings of her arrangements. Figs. 1 and 2 show the position of the pumps, and of the inlets and outlets. In this vessel two pumps were used, not because the designer thought it an advantage, but in order that a passage might be maintained from the forward to the after part of the ship below the deck. The performance of this vessel will likewise be found in Table 1.

Fig. 1



Longitudinal Section through Inlet of Swedish Hydraulic Vessel.

Fig. 2



Plan of Discharge-Pipes of Swedish Hydraulic Vessel.

In 1879, the "Fleischer Hydrometer," a ship of a different design, but still propelled by the reaction of jets of water, was built in Germany. In this vessel the water is acted upon directly by steam without the intervention of a pump. The arrangement is as follows:—There is a cylinder lined inside with wood, at the bottom of which is a large pipe leading to a nozzle at the bottom of the vessel. A float, of nearly the same diameter as the cylinder, works up and down in it. The cylinder being now full of water, and the float consequently at the top, steam is admitted by a valve above the float and driving it down, ejects the water through the nozzle. On reaching the bottom of its stroke, the float opens the exhaust, and the steam passes into the condenser. The vacuum thus created in the cylinder causes the water to rise partly through the nozzle, but principally through a suction-valve in the bottom of the condenser. The cylinder is thus filled with water, and the float rises to the top, in doing which it closes the exhaust and opens the steam-valve, when the operation is repeated. The loss by condensation appears, from the indicator cards, to have been much less than might have been expected in a cylinder filled alternately with steam and with water; but as the cylinder is not entirely emptied at each stroke, a layer of boiling water always remains at the top and adheres to the wooden lining

as the float descends. The vibration was enormous, and the jerky motion was very unpleasant at the earlier trials, but was somewhat lessened afterwards. The data obtainable are unreliable, as the speed is variously given as 9 and as 6 knots per hour, and there is no means of ascertaining the loss between the boiler and the indicator, which is probably large. As the down stroke is made by the pressure of the steam and the upstroke by the pressure of the atmosphere, it is probable that the upstroke occupies the longer time. Water is ejected and propelling takes place during the down stroke; therefore, in order to eject a given volume of water per second at a given mean velocity of discharge, it is necessary either to have two or more pumps where one would be sufficient if the action were continuous, or the actual velocity of discharge must be at least double, and probably, more than double the mean velocity. Either plan produces loss of efficiency.

The advantages claimed by the advocates of the hydraulic system of propulsion may be enumerated as follow:—No impediment to speed under sail; no racing due to pitching; no vibration; power of reversing-motion in the hands of the officer on deck; full engine-power for manœuvring; vessel capable of being made double-ended, and power of ramming much increased. The propeller is not liable to damage from running aground, and cannot be fouled by floating obstructions; it is favorable for light draught; and the large pumping power is available for keeping down leaks. The disadvantages of the hydraulic propeller are mainly these: First and foremost is the difficulty of utilizing the full energy of the feed-water, or the velocity of the water entering the propeller. Secondly, every particle of water acted on must be carried in the ship. Thirdly, the loss by friction of the water in the passages. Fourthly, the loss by bends in the pipe, which can only be reduced by increasing the losses from the second and third causes, namely, the weight of water carried, and the friction of the passages.

The advocates of the system of hydraulic propulsion were not satisfied with the Waterwitch as an embodiment of their ideas. They were supported in their demands for a further trial by Lord Dufferin's Committee on Designs in 1871. This Committee, which numbered amongst its members, Sir William Thomson, Professor Rankine, and Mr. Froude, inserted the following clause in their report:

"Our attention has been directed to the hydraulic method of propelling steam ships, with reference especially to vessels of very light draught, and intended for service in waters which are so shallow as scarcely to afford sufficient immersion even for twin screws, or in which there is reason to apprehend that the screws are likely to be fouled by obstacles placed there for that purpose. Regarded in this light, we are of opinion that the system is deserving of a more thorough trial than it has yet received, and we beg leave to recommend the subject to their Lordships' consideration accordingly." The Admiralty hesitated long before doing so, but were finally induced in 1881 to order one of a number of second-class torpedo boats, then being built by Messrs. Thornycroft, to be fitted with a turbine propeller. It was intended that the boat should be as much as possible like one of the screw-boats, in order that the performance of the two might be compared. It was, however, soon found desirable to make certain modifications in the form of the hydraulic-boat, the reasons for which will be explained. The conditions laid down by the Admiralty were that a similar boiler was to be used to that in the screw-boat, and about the same H.P. developed, and that the builders were to obtain as much speed as they could.

The number of revolutions made by the engines of the screw-boats are about six hundred and thirty per minute. This was considered much too high a velocity for the turbine, and its revolutions were fixed at four hundred per minute. This involved larger cylinders. Those of the screw-engines were 8¼ inches and 13½ inches in diameter and 8 inches length of stroke; while those of the hydraulic engines were increased to 8½ inches and 14½ inches in diameter and 12 inches length of stroke; and, although the latter were relieved of the weight of the reversing gear, they were still considerably the heavier, the former being 1.9 ton, and the latter, including pumps and water in pipes 2.58 tons. The total weight of machinery, including water in

the boiler, &c., is, for the screw, 4.87 tons; for the turbine 5.56 tons.

It was felt that a vessel of the same dimensions as the screw-boat would be much handicapped by this extra weight, as the whole displacement of the latter is only 12.9 tons. The length was therefore increased from 63 feet to 66 feet 4 inches, and this, together with a modification of the bottom, which gave some extra displacement, restored the boat to about the same draught amidships as the screw type.

The difference observable in the disposition of the machinery was dictated by the necessities of trim. This explains why the boat, intended for comparison with a similar vessel driven by a screw, was not made of the same dimensions. The designers consider that the alterations render the conditions much more fair for the hydraulic boat than if no modification had been made. The difference in length tells slightly in favor of the longer boat.

It will be convenient here to glance at the causes of loss of work in propellers of different kinds, and the methods adopted for reducing them to a minimum in the boat under consideration. These causes of loss, irrespective of friction, may be thus summed up:

1st. Suddenness of change from velocity of feed to velocity of discharge.

2d. Transverse motion impressed on the water.

3d. Waste of energy of the feed water.

Propellers which suffer from the first cause of loss are, the ordinary uniform-pitch screw and the ordinary paddle-wheel; while those which, in varying degrees, avoid it are the gaining-pitch screw, certain forms of feathering paddles, Ruthven's form of centrifugal pump, and, probably best of all, the oar. Propellers which undergo loss from the second cause, namely, transverse motion imparted to the water, are ordinary screw propellers, radial paddle wheels and oars. This loss is greatly reduced in the guide blade, screw propeller, and is entirely avoided in the turbine propeller. The third cause of loss, that is, the waste of energy of the feed-water, is experienced only by the jet propeller, as it has been previously used, and it is from this cause principally that its inefficiency results.

In the boat under consideration, however, careful provision has been made to utilize as much as possible the velocity of the feed-water; and it is in this respect chiefly that she differs from the Waterwitch and from the Swedish boat, where nearly the whole of that velocity was lost.

In the Thornycroft hydraulic boat there is a sudden break in the bottom, just forward of the pump. The bottom at that point has been formed into a great scoop (Fig. 3), rising by a gentle incline to the inlet of the pump, which is placed at an angle, so as to reduce the change of direction imparted to the entering water as much as possible. The velocity of the water causes it to rise in the scoop, and the vanes of the pump are adjusted to pick up the water without shock, and gradually to accelerate it to the speed of discharge. Having now put the full energy into the water in the form of velocity, it is simpler to keep it as such, and to get rid of the water overboard as quickly as possible, instead of converting it, by means of a vortex chamber, into pressure, in order to reduce the friction through the pipes, as is generally done when the water is carried any distance. In the Swedish boat (Fig. 2) the outlets are carried to some distance ahead and astern. This was done, the author believes, to reduce the loss by sudden bends, and to increase the leverage for steering, as valves were put at the ends of the passage which were actuated by the steering wheel, and which diverted the water into an athwart-ship direction. This involved a large increase in the weight of water carried and in the friction.

The nozzles in the Thornycroft boat are 9 inches in diameter, and are formed of pieces of copper pipe bent to a radius of 18 inches. They are shown in Fig. 4. Each of these bent pipes is pivoted in such a manner at the point P that either end can be presented to the hole in the side of the boat. No valve is therefore required. The movement is effected by handles in the conning-tower.

There seems to be a considerable difference of opinion as to the best position for the inlet to the pump. Some say that it is immaterial where the water is taken in, while one distinguished engineer thinks that the inlet should be at the

stern. His idea, which at first sight seems reasonable, is, that by taking in at the after end, water which is at rest, as regards still water, then by a gradually narrowing channel and a gradually imparted acceleration, giving it a velocity v, equal to the speed of the ship relative to still water, and then turning it round and discharging it at the stern with a velocity v relative to the ship, and no velocity relative to still water, there is no slip. The efficiency then comes out to that extremely deceptive figure unity, and he states in a paper, "On the Efficiency of Jet Propellers," which appears in the Transactions of the Institution of Naval Architects, that this is a theoretically perfect propeller. This will be examined more particularly in the appendix, but looked at in a simple manner, suggested by Mr. Thornycroft, the result seems clear. As the propelling apparatus takes up water at rest at the stern and discharges it at the same place and in the same condition, and as the quantity discharged is equal to the quantity received, it seems evident that the inlet and the outlet might be connected together by a pipe, and the same water be passed round and round. The result is plainly no propelling power.

Another point to be considered was whether the outlets should be above or below water. The amount of water discharged, and the resultant reaction, are absolutely the same from a given orifice

Fig. 3

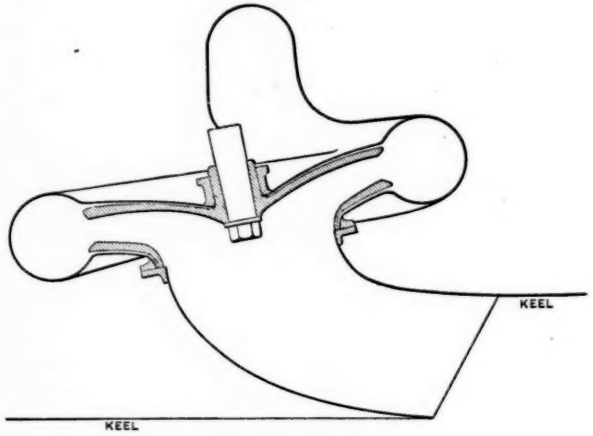
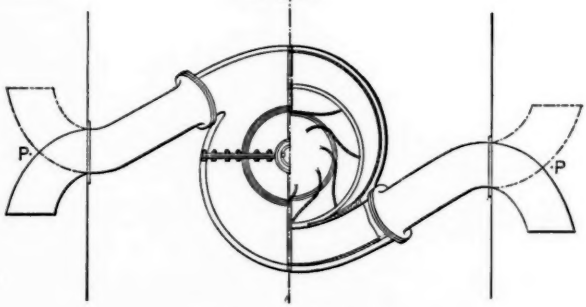


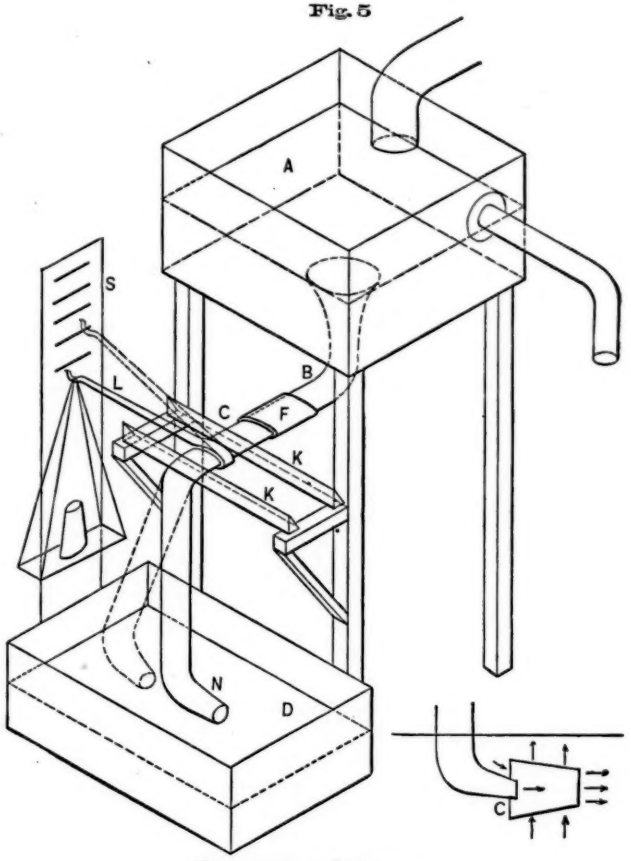
Fig. 4



THORNYCROFT DISCHARGE.

and a given head, whether that orifice be above or below water. But work is lost in raising the water above sea level. Another reason for keeping the orifices below the surface was that it was hoped some advantage might be taken of induced currents set up by the discharged water. Experiments were made upon

Fig. 5



Experimental Apparatus.

this point independently by Mr. Thornycroft and by the designer of the Swedish hydraulic boat.

In Fig. 5, A is a tank containing water which flows through the pipe B C, and is discharged by the nozzle N below the surface of the water in the tank D. The pipe B C is supported upon knife edges K K. The portion B of this pipe is connected with the part C by a flexible india-rubber pipe F, which permits C to swing back to balance the reaction of the water issuing from the nozzle N. A lever L is attached to the movable pipe C, upon the end of which weights can be hung. The nozzle N being stopped by a cork and the tank A and pipe B C filled with water, the position of the end of the lever L is noted upon the scale S. The nozzle is then uncorked and the water level kept constant in the tanks A and D. The pipe C swings into the dotted position. Weights are then placed on the lever L until it is brought into the old position,

and the moment of the weight balances the reaction of the jet.

If now a hollow truncated cone be placed over the nozzle and the water discharged through it, outside water is drawn through the annular opening *a*, and mixing with the jet has velocity imparted to it. There is a loss of pressure along the inside of the cone, and a corresponding increase along the outside which impels it forward, on account of its conical form, and increases the reaction of the apparatus. By placing two or three of these conical tubes one outside the other, as shown in Fig. 6, and thus reducing the speed of the discharged water, and increasing the volume, the reaction of the several cones considerably augments that of the original jet.

In one experiment five cones were used, and a jet driven by a small propeller was passed through them. They were so arranged that they could be slipped over the jet while the apparatus was working. A weight was lifted by the action of the jet, and the pull of the propeller alone was measured first. The cones were then slipped over it, when the pull was immediately increased in the proportion of 1 to 1½. The experiment gave such unmistakable results that much was hoped from it. When, however, the apparatus was drawn through the water, the friction against the larger surfaces counterbalanced any advantage in reaction, and it had to be abandoned.

Experiments with nozzles towed through the water and discharging below the surface, and then discharging above it, showed very clearly that the resistance of the nozzle far outweighed the loss by raising the water the extra height necessary to keep them above the surface.

Fig. 7 represents the curves of areas of the immersed portions of the hulls of the screw and turbine boats. The length of the former is represented by the base line B C, that of the latter by A B. Ordinates at any point measure the area of the section at that point. The area of the curves thus obtained gives the volume of the displaced water. B is the bow, and A and C are the sterns. It will be seen that there is a sudden increase in the sectional area amidships in the hydraulic boat. The height of the ordinate F D represents the area of the section just forward of the inlet to the pump. D E is the area of the inlet. Instead of the area abaft the inlet falling back again, as in all previous hydraulic boats, it is

Fig. 6

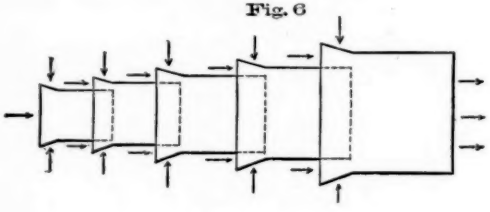
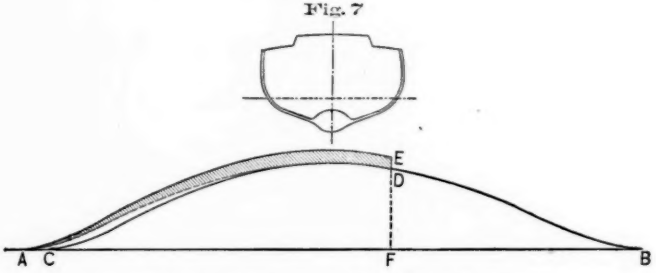


Fig. 7



CURVES OF AREAS AND SECTIONS OF INLET.

kept at the full amount FD+DE, and continues to the stern at the higher level. An amount of extra displacement, represented by the shaded portion, is thus obtained without the water being conscious of any discontinuity in the form, as the amount which has to be displaced to make room for the increased section is removed by the pump. When the section of the hull is kept the same before and abaft the inlet, fresh water has to flow in from the sides to supply the place of that passing into the pump, and probably disturbs the smooth action of the stream-lines.

It has not been found practicable to utilize the full pumping power of the engines for keeping down leaks. A centrifugal pump will not work unless fully charged; and the supply of water necessary in this case is so enormous in proportion to the size of the boat that large and complicated valves become needful for closing the inlet and throwing the pump into communication with the bilge, and then to supplement the bilge-water with water from outside as the former becomes insufficient to feed the pump. The difficulty is seen directly when it is stated that the pump delivers an amount of water equal to the whole displacement of the boat in fifteen seconds. Thus, although not impossible, it would have involved the addition of such a large weight, and the consequent loss of such an amount of efficiency as regards speed, that it was reluctantly abandoned, on the ground that nothing should be allowed to interfere with the highest possible speed being attained.

Although the double-ended form of hull, and the consequent advantage in power of ramming, would no doubt be adopted in an iron-clad, it is unnecessary in a torpedo boat, and some additional speed was anticipated from the retention of the ordinary form.

It has always been considered a feature in the hydraulic system that an equal speed is attainable ahead and astern. It is obvious, however, that the form of inlet adopted is unfavorable for going astern. As a general rule, anything designed for locomotion in more than one direction may always be adapted to give a better result when moving in one particular direction than in any other; and when there is an equal power of moving either forwards or backwards, it is possible to effect an improvement in one direction at the expense of the other. Vessels intended to navigate crowded rivers require some power of quickly reversing their motion; but for torpedo boats, which have to run rapidly up to an enemy and then escape from him, the case is different. The qualities required in torpedo boats are high speed and quick steering power. Several of the more recent inventions in screw propellers have had for their object the utilizing of the whole power of the engines for steering; and it is not improbable that, in vessels intended for this service, the complications necessary for reversing the engines may be done away with.

The performance of the boat is shown in Table 2. The quantity of water discharged was about 1 ton per second; the velocity of discharge 37.25 feet per second, and the speed of the boat 21.4 feet per second, or 12.65 knots per hour. The efficiency of the pump and jet combined, *i. e.*, useful work in jet divided by effective HP., was 0.33, and the total efficiency, *i. e.*, useful work in jet divided by indicated HP., 0.25.

The method adopted for measuring the volume of water pumped, and the velocity of discharge, was considerably more accurate than any hitherto employed. In the case of the Waterwitch, the only measurements taken were with a patent log hung in the jet, and the speed of discharge was not exactly known. The author has taken the efficiency as calculated by Mr. Brin, which gives the quantity and speed of discharged water shown in Table 2. This velocity, 29 feet per second, approaches very closely to the peripheral velocity of the wheel, $29\frac{1}{2}$ feet per second, and it is probable that the result is somewhat over-estimated.

In the Swedish boat a pressure-gauge was placed in the nozzle, and the calculations were made from the pressures found there.

In the new boat, a thin plate, $1\frac{5}{16}$ inch square, was attached to the end of a lever, and placed in the jet just where it left the nozzle. The pressure on this plate was recorded by a dynamometer attached to the other end of the lever. The apparatus was so arranged that the pressure could be measured at every point of the jet, and not in the center of the

stream only. The mean pressure in the jet was found to be nine-tenths of the pressure in the center. From this the velocity was estimated, and from the velocity, the quantity discharged. Fig. 8, curve A, shows the pressure in lbs. upon the $1\frac{5}{16}$-inch plate and lever carrying it, in the center of the jet, at different revolutions of the pump. Curve B shows the pressure upon the lever carrying the plate, plus a constant weight, and forms the zero. This curve was obtained by finding the pressure upon a similar lever without the plate. The difference between A and B is the actual pressure on the plate. A curve of the efficiency of the pump and jet at different revolutions is also shown.

Curves D and E correspond to A and B, but were measured when the boat was moored. As a test of the accuracy of the method of measurement, a dynamometer was attached to the stern of the boat, and the actual pull found at a given number of revolutions. At two hundred and ninety-five revolutions, the reaction estimated from the curve was $9\frac{1}{2}$ cwt. The pull recorded by the dynamometer

Fig. 8

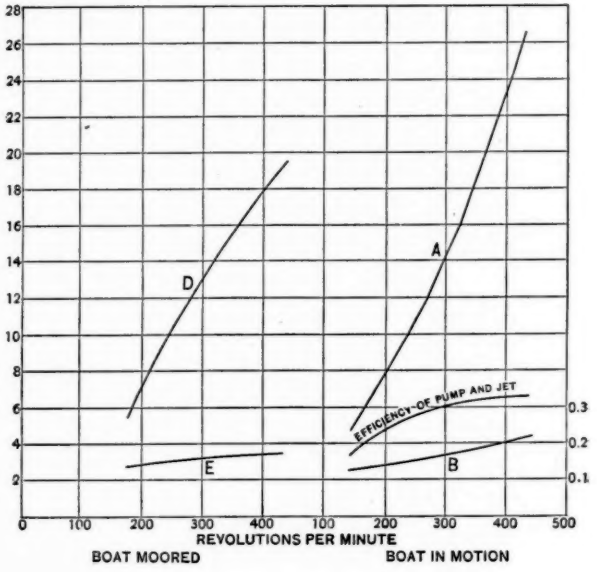
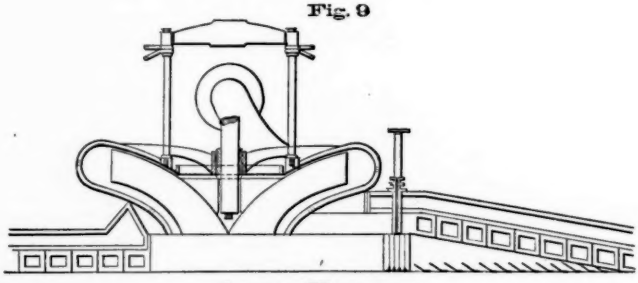


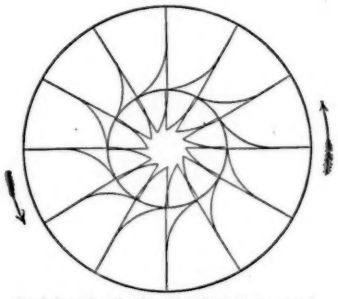
Fig. 9



Inlet of Waterwitch.

was 9¼ cwt. This was considered very satisfactory, and shows that the efficiency is, at any rate, not over-estimated.

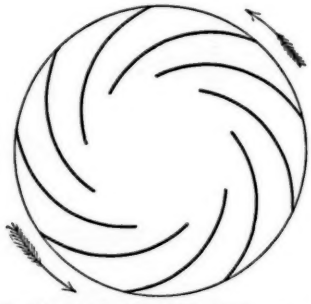
Fig. 10



Peripheral velocity 29.6 feet per second.

WATERWITCH PUMP.

Fig. 11



Peripheral velocity 39.36 feet per second.

SWEDISH PUMP.

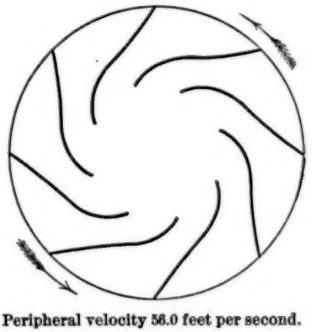
It is possible from the two curves A and D to estimate the effect of the form of inlet upon the efficiency of the jet.

The indicated HP. for a given number of revolutions was found to be the same in both cases. At four hundred and twenty-eight revolutions, the mean pressure when moving was considerably more than the pressure at the same number of revolutions and indicated HP. when moored. This excess of pressure was due to the energy of the feed-water, and corresponded to a velocity of 20.6 feet per second. This shows that only 0.8 foot per second of the full velocity of the boat was lost.

The efficiency of the jet thus appears to be 0.71, and of the pump, 0.46. The calculations are given in Appendix I. In the case of the Waterwitch, where the whole of the velocity of the feed was lost, the efficiency of the jet was 0.5, and of the pump, 0.47. In the Swedish boat, under similar conditions, the jet gives 50 per cent., and the pump 55 per cent. In this boat an alteration was afterwards made in the inlet, as shown in black lines in Fig. 1. and the speed was thereby raised from 7.87 knots to 8.12 knots.

The measurements were all taken, and the efficiency calculated under the original conditions when the speed was 7.87 knots. The actual HP. expended in driving the vessel at this speed was $78 \times 0.214 = 16.7$. Suppose this to be increased as the cube of the speed, the actual HP. for 8.12 knots would then be 18.4. This raises the total efficiency to $(18.4 \div 78) = 0.236$.

Fig. 12



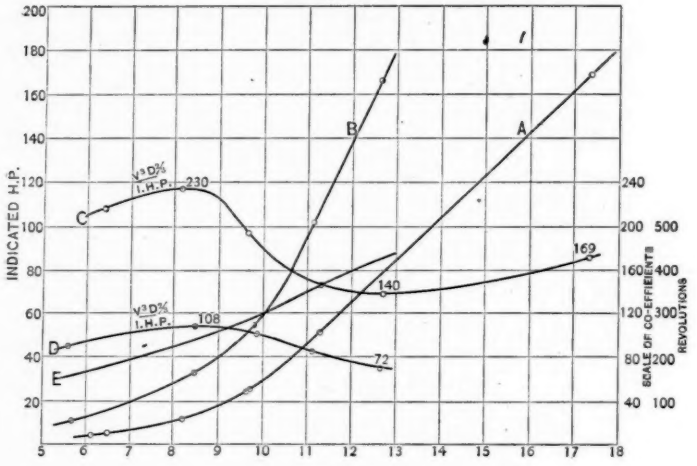
Peripheral velocity 56.0 feet per second.

THORNYCROFT PUMP.

It can be deduced from this that the speed of discharge was raised from 28 to 29 feet per second, corresponding to an increase of head of nearly 1 foot. The velocity of the stream entering the turbine would appear to be only 7.48 feet per second, or a little more than one-half of the speed of the boat. The efficiency of the jet is increased from 0.5 to 0.567. Figs. 10, 11 and 12 show the three forms of centrifugal pump, all reduced to the same diameter.

It should be remarked that the comparison between the performances of the Waterwitch and of the two smaller boats, on the basis of the displacement

Fig. 13



E. Curve of revolutions, and speed of Hydraulic boat.

CURVES OF HORSE-POWER AND SPEED.

formula given in Table 1, is not a fair one. The coefficient is taken at the maximum speed in each case, and the Waterwitch gives a very good coefficient. But 9.3 knots per hour is an easy feed for a vessel of her length, while 12.6 knots is a very difficult one for a boat only 66 feet long.

It is alike unfair to compare the coefficients of the two Thornycroft boats at 12.6 and at 17.3 knots.

Fig. 13 shows the HP. required for different speeds, and the value of the coefficient $\frac{V^3 D^{\frac{2}{3}}}{I.HP.}$. A is the curve of power and speed of the screw-boat; B, of the hydraulic-boat; C and D show the respective coefficients at different speeds. It will be seen that at 12½ knots the coefficient is at its worst, and that afterwards it steadily improves. The comparison between these two should be taken at 12.6 knots for both boats. The hydraulic is then 72 and the screw 140. This ratio is almost the same as the ratio of the efficiency, 0.254 to 0.5. The maximum performance of the Thornycroft was 108; that of the Waterwitch, 116. It will be asked, how is it that, although the efficiency of the new hydraulic machine is higher than that of the Waterwitch, yet the latter gives a better coefficient even at corresponding speeds? Looking at the curve of coefficients Fig. 13, it will be seen that the maximum occurs at 8½ knots. This corresponds to two hundred and thirty-five revolutions of the pump. In Fig. 8 it is shown that the efficiency of the pump and jet is only 0.26 at two hundred and thirty-five revolutions. If the pump had been designed to run at its maximum efficiency at the speed which best suited the boat, a much better coefficient would have been obtained. The indicated HP. at 8½ knots was 33. This multiplied by the maximum efficiency of pump and jet, 0.33, and divided by the efficiency at 8½ knots, 0.26, gives 42 indicated HP.; this would admit a speed of 9.2 knots. This speed of 9.2 knots, which would have been obtained with 33 indicated HP. if the efficiency of the hydraulic machine had been 0.33 instead of 0.26, gives a coefficient of 140 against 116 in the Waterwitch.

In conclusion, it is worthy of note that one of the greatest obstacles to the success of the jet-propeller, namely, the loss of energy of the feed-water has been overcome. It was clearly foreseen by

Mr. Thornycroft, and by adapting the bottom of his boat to meet it in the manner described, he has raised the efficiency of the jet from 0.50 to 0.71.

Unfortunately this obstacle did not stand alone. What efficiency it is possible to get with a centrifugal pump delivering a ton of water per second, with a lift of 21½ feet and of limited weight and dimensions, the author cannot say. Forty-six per cent. seems very low. Had it reached 70 per cent. the total efficiency would have been 0.385, and the speed upwards of 15 knots. Perhaps this amount of success may yet be achieved for the hydraulic propeller, but it is not likely to be exceeded.

The case at present stands somewhat thus:

In the screw-boat the efficiencies are—Engine, 0.77; screw propeller, 0.65; total, 0.5.

In the hydraulic-boat—Engine, 0.77; jet propeller, 0.71; pump, 0.46; total, 0.254.

The jet as a propeller may be taken as a little better than a screw, but the loss in the pump is a dead loss, and represents about half of the power. In other words, before a hydraulic-propelled boat can be made to compare favorably with one driven by a screw, the pump producing the jet must work without loss.

NOTES ON THE INSPECTION OF METALLIC STRUCTURES.

By JAMES SANDERSON, C. E.

Papers of the Engineering Society of the University of Michigan.

Midway between the engineer and the mechanic, in the chain of those whose industry builds up the great structures of the day, stands a class of persons who are supposed to be possessed, to a certain extent, of the qualifications of both the other classes. These are called inspectors, and their duty is to follow closely the labor of the workman who embodies in material form the ideas of the engineer, to see that the work is well done, and that the results are in accordance with the guiding plans and specifications.

It is quite possible that certain parts of the inspector's experience may be of value to the engineer; for the former comes more closely in contact with actual materials and workmanship than does the latter, and may be expected to observe some things which his employer has no opportunity of seeing. Therefore I make no apology for bringing to your notice a few items from such an experience in connection with the building of iron and steel structures, hoping that, although meager and loosely thrown together, and hardly in the line of engineering studies, they may yet be of some interest, and, possibly, of some value.

One of the things with which the inspector is supposed to deal is the testing of pieces of metal, and of entire members of different kinds. In this, however, my own experience, though perhaps extensive enough in amount, is limited in kind, being confined to the testing of tension pieces, and particularly of eyebars.

It is customary in some shops, and required in the specifications of many structures, to test each eyebar used in a bridge or a roof, to an amount exceeding by one-third to one-half, the working load of the member. In steel bars the elongation produced by this test is often measured, as an indication of the uniformity, or otherwise, of the material, with respect to its modulus of elasticity. For measuring this elongation, various apparatus may be used. I shall describe briefly the one I employed:

It consisted mainly of two flat wooden rods, each of them half as long as the part of the eyebar to be measured. The rods lay along the upper edge of the bar, but were prevented from touching it by small, smooth pieces of hard wood, about an eighth-inch in thickness, tacked to the under side, one on each end of each rod. The rods were clamped down to the bar at their outer ends, by ordinary joiners' clamps, placed directly over the small

wooden blocks. Thus the movement of the rods, as they slipped to and fro on the blocks at the inner ends, indicated the extension and the contraction of the bar between the two points at which the rods were clamped. To assist in measuring this movement, a small steel plate was secured to the top of each rod, at its inner ends, and the distance between the inner edges of these plates, before, during, and after the test, was taken by means of verniered calipers, which read to 1-1000 of an inch.

As to the results of such tests, there is nothing in them worthy of special remark here. The elongations obtained would, of course have been different in steel of a higher or lower grade, and would, therefore, be no standard for other cases.

When it was desired to make tests to rupture, in which the space under measurement was usually less than in routine tests of eyebars (the bars themselves being, as a rule, smaller) a somewhat different apparatus, was used. There was but one bar, instead of two, and this was clamped at one end and free at the other. To the free end was fastened the measuring apparatus, consisting, essentially, of a small steel roller, bearing a long, light, radial arm of steel. The roller, which rested on the top edge of the test-piece, was roughened, so as to roll upon it without slipping, and as it revolved, the end of the steel arm moved around a brass arc, upon which were marked, in a greatly exaggerated scale, the distances passed over by the periphery of the roller.

In making a test to rupture, the particulars noted were usually the following, viz.: Original size and length of bar; thickness of head and size of pin-holes (if an eye-bar); distance between witness-marks before test; stretch (in the portion of the bar under the measuring rod) at tensions of 10,000, 15,000 and 20,000 lbs. per square inch, respectively, the bar being released from tension after each reading; stretch at 21,000, 22,000 lbs, per square inch, the bar being relaxed after each pull as before, until it showed permanent set; amount of permanent set, and the tension at which it occurs; total pull at the instant of rupture; size of bar, after test, at point of rupture; distance between witness-marks after test. From the last two items are deduced the reduction of section and the elongation, which indicate the comparative ductility or brittleness of the material tested. The tension at which the first *perceptible* permanent set occurs is taken as the elastic limit (proof strength) of the piece. I am aware that Rankine objects to this method of measuring the proof strength, as unscientific; but it gives results which are satisfactory for practical purposes, and for shop-work, where dispatch is needed, rather than scientific nicety, it is far preferable to the cumbrous process described by Rankine himself. (See *Civil Engineering* § 144.)

Much is sometimes made of the appearance of a fracture on a piece of iron, as indicating its quality; and a practiced eye may, indeed, discriminate between coarse and fine metal by examining the broken ends of a bar. But I am of the opinion that little dependence is to be placed upon the supposed difference between iron which shows a "fibrous," and that which shows a "crystalline" fracture. I have frequently seen the same break show patches of each kind of fracture, and that, too, where I was practically sure that the texture was uniform. The difference seemed to lie not so much in the quality of the iron, as in the manner in which it had been broken. Where, for example, the fracture was in the nature of a cross-break, it had a crystalline appearance, but where it ran along the grain, like a tear, it looked fibrous. In other words, the so-called "crystals" seemed to be merely the squarely broken ends of fibers, which, when drawn out into points, would have brought a "fibrous" fracture. And, in general, the causes producing one sort of break or the other, seemed rather external than structural. For instance, when a piece was broken suddenly, as by a blow, or was nicked, and then bent cold, the resulting fracture was almost invariably crystalline; but when it was pulled steadily until rupture took place, or was bent without nicking, the break generally looked fibrous. In this respect, iron seems to behave much like pitch, and other ductile substances, which, when drawn out slowly, will run to a point, or break like a bunch of fibers, but, if struck or jerked suddenly, will crack with a smooth conchoidal fracture corresponding to one of the crystalline surfaces or facets of the broken metal.

Aside from the matter of tests, there are many points requiring the inspector's attention, but few, perhaps, that can be verbally explained. As with the "knacks" and turns of any trade, an acquaintance with them presupposes personal contact with materials and work. There is, however, one subject of considerable importance, though seemingly a small one, about which a few things may, I think, profitably be said. It is the subject of looseness in rivets.

The rivet, more than any or all other forms of fastening, is used in connecting the parts of iron or steel structures; and it is doubtful if anything will ever be devised to take its place. Nevertheless, as at present used, it is subject to certain disadvantages and accidents of workmanship, which it is the business of the inspector to detect, and of the engineer to remedy or to prevent.

Perhaps the most important of these drawbacks is the liability of rivets to looseness. The object of almost all the rivets in an engineering structure, is to carry transverse shear. To be convinced of this fact, if conviction be needed, one has but to consider the relations which the parts of a built member bear to one another, and the fact that the rivets joining them are driven at right angles to the principal lines of stress.

Now, if a rivet be loose, *i.e.*, if its shank be separated, by any appreciable space whatever, from the sides of the hole which it is supposed to fill, it is evident that it can take up, from the pieces which it connects, none of the shear intended for it, and that its hole might as well be empty. To detect this looseness in rivets, so as to have the matter corrected, is part of the inspector's duty. But as in other cases, so in this, prevention is far better than cure; and if means can be found to insure the tightness of rivets in the first place, the results will be far superior to those produced by any amount of cutting out and replacing. If, therefore, the experience of any number of inspectors or observers shall aid in discovering the causes or conditions of looseness, so that these may be removed, much will have been effected.

It is impossible, however, to lay down any infallible rules as to the parts of iron or steel structures where most loose rivets are to be found. I do not know of many other cases where it may be more truly said that "exceptions are the rule;" and therefore, while I think that the few general statements I shall make below will prove true in the long run, they may very possibly be false guides in any given case, and are only to be taken as expressions of the average of results.

1st. Hand-driven rivets are more apt to be loose than those driven by power, and are more irregularly loose. That is to say, supposing an equal number of rivets to be loose in each of two members, one power, and the other hand-riveted, the loose rivets in the former are likely (if numerous) to occur in groups and series; while, in the latter they will probably be scattered, without any regularity, over the member.

2d. Counter-sunk rivets are more apt to be loose than those with ordinary round heads. Whether rivets counter-sunk on both sides are more frequently loose than those with one full head, I am unable to say, as it is generally impossible to test double-counter-sunk rivets for lateral looseness. However, such rivets will frequently move longitudinally in the hole, which is not true of the most full-headed rivets.

3d. Rivets connecting thick plates, or pieces of metal, are more likely to be loose than those in lighter work.

4th. Rivets holding lattice-bars or light cover-plates to flanges of channels, &c., are very seldom loose. If, however, a rivet passes through two or more thicknesses of metal besides lattice-bar or bars, or a cover-plate, its liability to looseness is increased in proportion to the extra thickness of metal passed through.

5th. Pin-plates, and other reinforcing plates, especially when fastened by staggered rivets close together, are likely to have some loose ones. In general the closer the rivets together, the more apt are some of them to be loose. In long, regularly spaced rows, the rivets are less apt to be loose than when crowded or bunched.

6th. In rows of rivets, those at or near the ends are most apt to be loose. When the end rivet of the row is tight, a loose one may frequently be found second or third from the end.

7th. Other circumstances increasing the liability to looseness, will suggest themselves. For example, when rivets

have to be cut out, and others driven to replace them, the shock of the cutting and redriving is very apt to loosen rivets, previously tight, in their neighborhood. This makes a loose rivet a spreading evil, and one which is peculiarly difficult to remedy. Again, it will readily be seen that, in hand-riveting, any rivet, either of whose heads is hard to get at for the purpose of holding, or heading up, is likely to prove loose. Also, that it is difficult to make a tight rivet at or very near the angle of a bent piece, or at any point where it is not easy to bring the parts together. This, too, is evident, that a rivet, in order to be tight, should fit the hole as closely as possible before driving, and should be long enough to admit of being well headed up when in the hole. A small, half-formed head is a frequent accompaniment of a loose shank.

8th. I have not found that rivets holding together a large number of moderately thick plates, are especially apt to seem loose under the hammer. I doubt, however, if such rivets actually fill the holes. I suspect that a section of such a rivet would show it to be bent in the hole, and so held apparently tight, while not actually so.

9th. It stands to reason that a fairly punched and reamed hole is more apt to contain a tight rivet than is an irregular one; but I do not think, from my experience so far, that drilled holes (like those generally used in steel-work) will prevent loose rivets, or even greatly diminish their number. This, of course, is not the primary object of drilling the holes in steel, but I supposed, at one time, that a great diminution in the proportion of loose rivets to tight ones would be one of the results of the process; and in this expectation I have been somewhat disappointed. This much may be said, however,—that, in a rough hole, a slight looseness may not be detected, as a rivet may be jammed, so to speak, between projecting points; while, in a smooth, drilled hole, the slightest space between the rivet and the surrounding metal will cause motion under the hammer.

10th. After all endeavors to account, in some systematic manner, for the looseness of rivets, there is left a large margin of irregularity and absolutely nothing can be said with certainty as to the rivets in a particular piece of work, until they have been tested. Out of ten similar pieces, similarly riveted to all appearance, nine may show only one or two loose rivets each, while the tenth may look, after testing, and marking, like a constellation of chalk-circles. And even then, it cannot be said that all the loose rivets have been found, but only that none more are *known* to exist.

11th. For the detection of loose rivets, the only method I know of is to strike each rivet with a hammer. In my experience, the motion indicating looseness is more reliably ascertained by touch than by sight or sound. As to the precise manner of testing, it will, of course vary with individuals. My own method has been somewhat as follows: I strike a couple of blows with the hammer on each side of the rivet-head, placing the finger, at the same time, on the opposite side of the head, and in contact with the surface of the plate or piece riveted, so as to feel the motion, if any, between the rivet-head and the solid metal. The motion is much more readily felt by touching the head which is struck, than by holding the opposite head of the rivet, as is sometimes done. Looseness is also more readily detected by striking the original head of the rivet than by striking the head which is made in riveting.

In inspecting rivets counter-sunk on both sides, the only possible test is obtained by striking directly on the head of the rivet, at the same time placing the fingers on the opposite head, to detect longitudinal motion. This should be done, if possible, from both sides of the part riveted.

A light hammer (about one or one and a half pounds) is preferable to a heavy one. The blows struck should not be too strong, but such as may be struck freely from the wrist.

THE mean spotted area of the sun was slightly greater in 1883 than during preceding year, although the faculæ showed a small falling off. For 1883 Greenwich Observatory photographs are available on 215 days, and Indian photographs filling up gaps in the series on 125 days, making a total of 340 days out of 365 on photographs measured. In 1882 the total number of days was 343, viz., Greenwich series 201 days, supplemented by Indian photographs on 142 days.

PHYSICAL TESTS OF MALLEABLE CAST IRON.

By Prof. PALMER C. RICKETTS.

Written for Van Nostrand's Engineering Magazine.

The physical tests of malleable cast iron here recorded were made on the 50,000 pounds Olsen testing machine of the Rensselaer Polytechnic Institute. The metal was procured from two different manufactories in different States, and the iron from which it was converted was cast from patterns made specially for test specimens. Results were also obtained for some of this cast iron in tension and as beams in order to compare it with the malleableized material.

Strains for given increments of stress for a few of the bars in tension are given in Table VI., *but the "elastic limit" given in the tables is the stress at which the metal refused to hold up the scale beam*, and does not give the point below which the ratio of stress over strain is essentially constant. So determined, being a function of the time, it may be stated that except in cases where the strain was measured, no longer time was allowed, within the "elastic limit," than that necessary for the beam to come to rest. After this point was reached the piece was immediately broken in a length of time, counted from the first application of stress, varying from 9 to 15 minutes. When strains were measured the time varied from 20 to 30 minutes.

The dimensions of the specimens though recorded to hundredths of an inch were measured to thousands, and where increased accuracy would result, were so used in the calculations. Generally, however, the measurements taken showed that on account of the variation in cross-section of the material no such increase would be so obtained.

The bars whose tensile strength was determined were gripped by wedges resting in ball and socket joints, and with the exception of those recorded in Table V. were tested as they came from the furnace with the "skin" on. In these bars the length in which the elongation was measured always contained the fractured section, and in the tables the reduction of area at this point is given as a per cent. of that of the original section. The intensity of stress is also given in terms of the original section.

In Table I. is given the results of the tests of square bars of malleable cast and cast iron. The pattern from which Nos. 1 to 10 were cast was 14 inches long, and one inch square near the ends. About 4 inches from the ends it was beveled down to the section given in the third column, the length of the middle part being 5.5 inches. The elongation was measured in 5 inches in all of the malleable specimens. Nos. 9 and 10 were fractured at the bevel, as was always the case with the cast iron when not of uniform cross-section throughout. The malleable iron never broke at this point.

Nos. 11 to 17 were bars of nearly uniform size, Nos. 11 and 12 being the two ends of the same 24-inch piece, which was sawed in two at the middle before testing. The variation in ultimate resistance of these two is seen to be about two per cent. of the greater. No. 13 was 24 inches in length, and after it had been pulled apart one of the pieces, 18 inches long, was again subjected to tension, and the result is shown as No. 14. The ultimate stress was greater in the latter case than in the former, and it is believed that this may happen with any specimen, as the variation in the material of the same bar may be more than great enough to cover any diminution of resistance caused by the bar having been previously broken. In No. 14 the elongation in 10 inches was 0.19 inch, giving 1.9 per cent., whilst in 5 inches it was 0.11 inch, giving 2.2 per cent. as shown.

The rectangular bars in Table II. were 20 inches long, the middle 10 inches of each being of the size there given. The ends clutched were 1.20×0.45 inch in cross-section, and were beveled down to the smaller central part. The elongation was measured in 7.5 inches. No. 2 broke at an imperfection. The increments of strain for 1,000 lbs. increments of stress of Nos. 6 and 7 are given under Nos. 7 and 8 of Table VI. Nos. 8 and 9 of the cast iron broke at the bevel and the cen-

TABLE I.

TENACITY, ELONGATION, AND REDUCTION OF AREA OF SQUARE BARS OF MALLEABLE CAST IRON AND OF CAST IRON.

No.	Metal.	Dimensions of Specimen in Inches.	Stress in Lbs. per Sq. In.		Final Elongation per cent.	Reduction of Area per cent.
			Elastic Limit	Ultimate.		
1	Malleable cast iron..	0.78×0.78	1150	39400	4.6	7.2
2	" " ..	0.79×0.78	1140	39560	5.0	7.0
3	" " ..	0.79×0.79	800	40480	6.0	7.2
4	" " ..	0.79×0.78	1130	36130	6 6	6.4
5	" " ..	0.79×0.78	980	37190	4.4	6.4
6	" " ..	0.79×0.78	980	39480	5.0	6.9
7	" " ..	0.81×0.80	1080	44290	7.6	8.0
8	" " ..	0.80×0.78	810	42100	5.8	6.4
9	Cast iron.....	0.77×0.77	500	19360		
10	"	0.77×0.76	510	20450		
11	Malleable cast iron..	0.74×0.73	3680	34070	2.2	6.8
12	" " ..	0.73×0.72	2390	33400	1.8	3.5
13	" " ..	0.75×0.75	1770	30970	2.0	4.1
14	" " ..	0.75×0.74	1260	31980	2.2	4.4
15	Cast iron.....	0.76×0.74	540	22320		
16	"	0.74×0.73	550	25780		
17	"	0.75×0.74	630	20650		

TABLE II.

TENACITY, ELONGATION, AND REDUCTION OF AREA OF RECTANGULAR BARS OF MALLEABLE CAST IRON AND OF CAST IRON.

No.	Metal.	Dimensions of Specimen in Inches.	Stress in Lbs. per Sq. In.		Final Elongation per cent.	Reduction of Area per cent.
			Elastic Limit	Ultimate.		
1	Malleable cast iron..	1.02×0.38	3850	33800	2.3	5.6
2	" " ..	1.02×0.39	3770	32750	2.0	6.1
3	" " ..	1.02×0.40	3680	34250	1.6	6.9
4	" " ..	1.01×0.39	2300	36990	3.2	7.7
5	" " ..	1.00×0.38	1320	34870	2.3	7.4
6	" " ..	1.02×0.39		35000	2.7	5.5
7	" " ..	1.01×0.39		33600	2.8	7.2
8	Cast iron.....	0.99×0.38		14630		
9	"	0.99×0.38		19410		
10	"	0.99×0.38		27660		
11	"	0.99×0.38		29440		

tral part of the specimens when tested gave the results shown by Nos. 10 and 11.

All the pieces in the following table, except Nos. 7, 8 and 9, were larger at the ends, and the smaller middle portion was 10 inches long. The three exceptions noted were 24 inches long and of approximately uniform cross-section. In No. 7 the elongation in 7.5 inches was 0.34 inch, or 4.5 per cent., as shown, and in 9.5 inches it was 0.38 inch, or 4 per cent., both lengths containing the fractured section. The cast iron broke at the bevel between the lesser and greater cross-section, without perceptible elongation or contraction.

Table IV. contains results of tests of bars

Table III.

Tenacity, Elongation, and Reduction of Area of Circular Bars of Malleable Cast Iron and of Cast Iron.

No.	Metal.	Diameter of Specimen in Inches.	Stress in Lbs. per Sq. In.		Final Elongation per cent.	Reduction of Area per cent.
			Elastic Limit	Ultimate.		
1	Malleable cast iron..	0.59	2600	36600	2.7	14.7
2	" " ..	0.60	2300	37800	3.1	9.9
3	" " ..	0.57	2400	38400	3.2	10.3
4	" " ..	0.57	2200	39200	3.3	10.3
5	" " ..	0.55	1700	44680	5.1	10.6
6	" " ..	0.54	2190	43640	4.8	10.3
7	" " ..	0.51	1970	39160	4.5	10.3
8	" " ..	0.51	2900	36230	2.5	5.7
9	" " ..	0.53	2260	36200	2.0	8 1
10	Cast iron.....	0.56	1440	23050		
11	"	0.55	1920	22650		

Table IV.

Tenacity, Elongation, and Reduction of Area of Circular Bars of Malleable Cast Iron and of Cast Iron.

No.	Metal.	Diameter of Specimen in Inches.	Stress in Lbs. per Sq. In.		Final Elongation per cent.	Reduction of Area per cent.
			Elastic Limit	Ultimate.		
1	Malleable cast iron..	0.79	2040	29390	0.4	7.4
2	" " ..	0.81	1370	28570	0.8	3.9
3	" " ..	0.79	1120	33670	2.5	5.0
4	" " ..	0.79	1330	39430	3.7	4.4
5	" " ..	0.79	1440	40860	4.1	9.0
6	" " ..	0 80		32300	0.8	3.2
7	" " ..	0.79		32900	1.2	0.0
8	" " ..	0.79		36700	1.4	5.4
9	" " ..	0.79		36900	2.0	7.9
10	" " ..	0.79		36000	1.5	6.7
11	" " ..	0.81		32400		2.7
12	" " ..	0.81		29900	0.0	0.0
13	" " ..	0.78		34500	1.6	1.1
14	Cast iron.....	0.78	1150	21350		
15	"	0.78	940	27820		
16	"	0.78	930	24840		

of uniform cross-section 20 inches long. In Nos. 6 to 10 inclusive the elongation was measured in 10 inches, and in the others in 7.5 inches. It was not measured in No. 11, which broke outside the marks. In Nos. 4 and 5 it was in 9.5 inches, 3.7 and 4.5 per cent. respectively, and in 11.5 inches 3.6 and 4.6 per cent. No. 2 broke at a fault. In Nos. 7 and 12 there was apparently no contraction at the fractured section. In the cast iron No. 14 broke at a fault and No. 15 in the wedges. In these last three pieces the elongation and contraction were too small to be measurable.

In Table V. the specimens were turned from bars of diameter, shown in column headed "original diameter." The smaller tensile resistance of this metal with the skin off is rendered evident. An average of 15 tests of bars like those in Table IV. with the skin on, gives a resistance of

TABLE V.

TENACITY, ELONGATION, AND REDUCTION OF AREA OF CIRCULAR BARS OF MALLEABLE CAST IRON WITH THE SKIN TURNED OFF.

No.	Original Diameter in Inches.	Diameter of Specimen in Inches.	Stress in Lbs. per Sq. In.		Final Elongation per cent.	Reduction of Area per cent.
			Elastic Limit	Ultimate.		
1	0.79	0.74	1180	29950	1.2	3.7
2	0.80	0.74	1160	28840	0.1	4.1
3	0.79	0.76		33300	1.3	5.1
4	0.79	0.74		34600	0.8	2.4
5	0.78	0.75		31700	1.1	3.8
6	0.79	0.73		30190	0.7	1.6
7	0.79	0.60	1430	26430	0.5	3.5
8	0.80	0.63	960	28110	1.1	3.7

34,600 lbs. per square inch, whilst the 6 tests below, of specimens of the same original diameter as those above, from which about one-fiftieth of an inch had been turned, give an average of 31,430 lbs. When the bars were turned still more until their diameter was reduced about one-fifth of an inch the average of Nos. 7 and 8 in the table gives 27,300 lbs.

The elongations corresponding to increments of stress, as given in the table below, were measured with an instrument constructed for Prof. Burr. Through each of its two-ring shaped parts, which encircle the bar to be tested, pass three converging screws with milled heads whose sharp-pointed ends penetrate the bars at sections whose initial distance from each other is known. Extending vertically upward from the lower ring and diametrically opposite to each other are two steel rods with polished tops. These are clamped tightly to the ring near one of their ends, and their polished tops are vertically under the pointed ends of two micrometer screws which pass through projections in the upper ring. The parts being fastened as described, and the micrometers being screwed down until their pointed ends are in contact with the tops of the rods, the readings are taken. This contact may be detected by the minute shadows on the polished surfaces as the points approach. When for a given increment of stress the bar stretches the points separate from the surfaces, and when again brought in contact the mean of the differences of the readings of the micrometers before and after the increment of stress is applied gives the corresponding strain. This instrument reads to ten-thousandths of an inch. Like other similar ones its object is to determine the point at which the ratio of stress over strain ceases to be essentially constant.

In Table VI., Nos. 3 to 8 give the strain, in 7.5 inches, for 1,000 lbs. increments, starting at 1,000 lbs.

In Nos. 1 and 2, for which the strain in 7.5 inches was also measured, the first contact was made at 300 lbs., but at these low stresses the results were not generally satisfactory, probably on account of initial bends. These strains are seen to be quite variable. Part of this is, of course, due to inaccuracies in setting and reading, but in the use of the same instrument on high steel, for instance, greater uniformity is obtained. The increase in the strains as the bars approach their ultimate resistances is evident. The micrometer was always removed when the breaking point was supposed to be near. No. 2 broke at 14,400 lbs., and No. 4 at 12,650 lbs.

In the lowest horizontal line is given the mean of the strains for the 1,000 lb. increments between 1,000 and 7,000 lbs. Taking the mean of the three corresponding to the circular sections with the skin on, we obtain for the ratio of stress over strain between the above limits 24,350,000 lbs. In like manner for the "rounds" with skin off, and the rectangular sections we get respectively 23,148,000 and 24,038,000 lbs. The bars in this table taken in their order from No. 1 are the same as Nos. 5, 1 and 13, Table IV., Nos. 6, 4

Table VI.

Strains in Bars of Malleable Cast Iron.

No.	1	2	3	4	5	6	7	8
Stress in Pounds.	Strains in Ten Thousandths of an Inch.							
	"Rounds," Skin on Mean Diameter, 0.79 Inch.			"Rounds," Skin off Mean Diameter, 0.74 Inch.			Rectangular, Skin on Mean Section, 1.02 × 0.39 In.	
300								
500	2.62	4.87						
750	1.75	0.87						
1000	1.25	4.87						
2000	5.00	2.50	7.37	6.75	5.25	5.62	5.00	7.00
3000	5.75	4.25	5.87	5.50	4.37	5.62	8.12	6.37
4000	5.00	7.12	8.00	8.75	7.12	10.62	9.75	7.62
5000	6.62	5.50	6.00	7.50	9.00	13.37	8.00	7.87
6000	7.62	6.12	8.00	7.75	5.50	8.25	9.12	7.50
7000	6.87	6.12	9.50	8.62	8.37	7.75	8.75	9.00
8000	5.62	8.25	7.12	11.25	10.75	7.37	11.00	11.12
9000	4.62	5.75	11.00	12.25	13.37	10.62	10.62	11.62
10000	5.12	6.87	14.87	19.50	14 25	14.62		
11000	8.00	9.12	15.75	36.12	22.50			
12000		9.87						
13000		18.87						
	6.14	5.27	7.46	7.48	6.61	8.54	8.12	7.56

Table VII.

Compressive Resistance of Short Blocks of Malleable Cast Iron and of Cast Iron.

No.	Metal.	Dimensions of Sections in Inches.	Length in Inches.	Stress in Lbs. per Sq. In.		Angle of Shear.
				Elastic Limit	Ultimate.	
		Rectangular.				
1	Malleable cast iron..	0.514×0.513	1.460	17000	128800	56°
2	" " ..	0.514×0.515	1.460	18900	109400	
3	" " ..	0.513×0.515	1.460	18900	108900	
		Circular diam.				
4	" " ..	0.510	1.248	15660	140200	61°
5	" " ..	0.508	1.252	9360	121230	57°
6	" " ..	0.509	1.249	15270	123150	60°
7	" " ..	0.592	1.246	10900	148400	47°
8	" " ..	0.591	1.246	9120	160950	47°
9	" " ..	0.590	1.247	10620	159340	42°
10	Cast iron.....	0.513	1.248	16900	144900	
11	"	0.506	1.248	16410	151700	62°
12	"	0.512	1.247	17560	158500	67°

and 5, Table V., and Nos. 6 and 7, Table II.

The compressive resistance of short blocks of square and circular section of this metal was found, and also that of three blocks of round cast iron. The dimensions of the pieces and the results of the tests are given in Table VII. All had the skin on with the exception of Nos. 7, 8 and 9, which had been turned

down from a bar 0.79 inch in diameter, the same bar given as No. 7 in Table V. With the exception of Nos. 2, 3 and 10, the specimens failed by shearing, the angle made by the plane of shear with a normal section being shown by the numbers in the last column. Nos. 2 and 3 failed without shearing, and were unable to raise the beam when their lengths were reduced to 0.98 and 0.99 inch. No. 9 sheared in two planes nearly at right angles to each other. No. 10 crushed down and broke in pieces with no well defined plane of shear. The angle of shear is seen to be greater in the cast than in the malleable cast specimens. A comparison of the specimens of the same diameter and length show that the compressive resistance of the malleable iron is about 0.85 of that of the cast.

Table VIII. gives the reduction in the length of the short blocks numbered from 4 to 9 in the preceding table. The cast iron specimens were reduced but slightly, at 20,000 pounds about 0.04 inch, compared with 0.25 inch for malleable specimens of the same cross-section.

Table IX. contains the results of experiments on beams of malleable cast iron to determine the center weight at the elastic limit and at rupture, and therefore the value of K, the intensity of stress in the extreme fiber at these points.

TABLE VIII.

REDUCTION IN LENGTH OF SHORT BLOCKS OF MALLEABLE CAST IRON UNDER COMPRESSION.

No.	4	5	6	7	8	9
Stress on Specimen in Pounds	Reduction in Length of Specimen in Inches.					
8000	0.04	0.04	0.04	0.04	0.03	0.03
12000	0.10	0.11	0.09	0.05	0.06	0.06
16000	0.19	0.19	0.19	0.11	0.10	0.10
20000	0.25	0.25	0.25	0.16	0.16	0.16
24000	0.29	0.47	0.47	0.23	0.23	0.23
28000	0.38			0.34	0.32	0.32
32000				0.39	0.39	0.39
36000				0.49	0.46	0.46
40000				0.59	0.54	0.54
44000					0.63	0.63

Two sets were made; in one the bars were, as shown, about 1.5 inch square, and in the other about half of that, the spans varying from 15 to 4 inches.

The larger bars used for the 6 and 4 inch spans had previously been broken as 15 and 12 inch beams. This made the second ruptured area 4 or 5 inches from the first, and it is believed that, from the nature of the material, the fact that the parts had been previously broken did not materially decrease their center-breaking weight in the shorter spans. This breaking weight in all the spans varied decidedly with the appearance of the interior of the bar. When this was homogeneous and dark, until the center was nearly reached, a greater resistance was obtained than when the center lighter part extended over a greater portion of the section. The results given for the smaller beams were obtained from two 24-inch bars, which were first broken at their centers as 15-inch beams, and their ends then used for the 9 and 6 inch spans.

In both sets it will be noticed that the results for any length of span are not very accordant and, on account of the fewness of the bars of smaller cross-section tested no deductions with regard to the value of ultimate K can be drawn, but from the larger ones the increase in its value with the decrease of span is clearly shown, though this could not always be inferred from the successive pairs. The means of these values for the successive spans from 15 inches down are 64,600, 54,000, 73,000, 78,600 and

Table IX.

Center Weight at the Elastic Limit, Center Breaking Weight, and Values of K at these Points for Beams of Malleable Cast Iron.

No.	Span in Inches.	Breadth in Inches.	Depth in Inches.	Center Weight at Elastic Limit. Pounds.	Center Breaking Weight. Pounds.	K. El. Limit. Pounds.	K. Ultimate. Pounds.	Deflection at Breaking in Inches.
1	15	1.47	1.51	2800	7750	18800	52030	0.29
2	15	1.48	1.50	5100	10250	34460	69260	0.96
3	15	1.51	1.53	1500	10700	9550	68000	0.99
4	15	1.52	1.52	1100	10800	7050	69230	0.99
5	12	1.50	1.52	2900	8750	15060	45450	0.29
6	12	1.51	1.49	3000	12900	16110	69290	0.65
7	12	1.51	1.52	2000	9100	10320	46960	0.11
8	9	1.49	1.49	2600	15500	10630	63410	0 32
9	9	1.51	1.53	2400	20200	9170	77180	0.54
10	9	1.53	1.53	1500	20700	5660	78110	0.50
11	6	1.46	1.50	2800	31000	7670	84930	0.35
12	6	1.51	1.52	1500	22200	3870	57280	0.15
13	6	1.49	1.44	1100	30800	3210	89870	0.41
14	6	1.50	1.51	700	31300	1840	82370	0.29
15	4	1.48	1.50	2100	37000	3780	66660	0.15
16	4	1.49	1.49	1500	47400	2720	85980	0.14
17	4	1.48	1.50	2400	37500	4320	67570	0.31
18	4	1.52	1.52	1500	50000	2560	85470	0.18
19	4	1.52	1.54	1500	50000	2500	84000	0.15
20	15	0.74	0.75	800	1300	43300	70310	2.25
21	15	0.73	0.73	750	1350	43380	78080	2.00
22	9	0.74	0.74	900	1950	29710	64360	0.52
23	9	0.72	0 73	1050	2500	36490	86870	1.50
24	6	0 72	0.74	900	3500	20756	80720	0.47
25	6	0.73	0.74	1200	3750	26960	84270	0.61

77,900. The small value for the 12-inch span is accounted for when it is stated that Nos. 5 and 7 were defective pieces, No. 5 breaking 0.25 inch from the center at a fault, and No. 7 one inch from the center at a section, a large portion of the area of which was light in color and non-homogeneous. No. 12 broke at a fault 0.5 inch from the center. In the 4-inch spans, although No. 15 did not break at a fault, the interior, lighter, weaker portion of the metal, formed a much larger part of the area of the section of fracture than usual, about 40 per cent. In No. 18 the stress was kept at 50,000 lbs. for 10 minutes, at the end of which time the bar broke, whilst in No. 19 the specimen was not broken, as it refused to yield after 50,000 lbs. had been kept on for half an hour. Hence the K for this bar is not ultimate K, and its mean value for this length of span is lower than it ought to be. The table also shows that the center weight at the elastic limit, and hence K at that point, though exceedingly variable for each span decreases decidedly with the length of the span.

The results for the smaller bars however, as well as those for the larger, serve to compare the resistance of malleable cast iron with that of the cast iron from which it was made. Experiments on the latter are given below, the spans being made the same so that the results are directly comparable. In the beams of smaller cross-section the center breaking weight of the cast iron in the 15, 9, and 6-inch spans was 69.0, 63.6, and

TABLE X.

CENTER WEIGHT AT THE ELASTIC LIMIT, CENTER BREAKING WEIGHT, AND VALUES OF K AT THESE POINTS FOR BEAMS OF CAST IRON.

No.	Span in Inches.	Breadth in Inches.	Depth in Inches.	Center Weight at Elastic Limit. Pounds.	Center Breaking Weight. Pounds.	K. El. Limit. Pounds.	K. Ultimate. Pounds.	Deflection at Breaking in Inches.
1	15	1.49	1.49	2400	4800	16330	32660	0.08
2	15	1.46	1.46	1000	5800	7240	41970	
3	9	1.48	1.48	1600	10100	6620	41740	0.05
4	9	1.47	1.50	1200	10400	4880	42260	
5	6	1.48	1.49	1200	13700	3290	37530	0.00
6	6	1.45	1.45	800	14000	2360	41380	
7	6	1.49	1.50	600	16600	1610	44560	0.02
8	4	1.46	1.50	1500	23200	2740	42370	
9	4	1.48	1.48	2000	19000	3680	34970	
10	4	1.48	1.49	1500	19500	2750	35820	
11	15	0.74	0.77		950		48720	0.18
12	15	0.73	0.74		850		47810	
13	9	0.72	0.73		1400		49250	
14	9	0.73	0.75		1400		45980	0.10
15	6	0.74	0.75	1900	2250	41050	48610	
16	6	0.73	0.74	1200	1700	27000	38250	
17	6	0.74	0.77	1000	2300	21040	48390	

55.5 per cent. respectively, of the malleable and in the larger beams of 15, 9, 6, and 4-inch spans, the per cents. were 53.5, 54.2, 51.4, and 46.4. Though the bars compared are not of exactly the same cross-section, these figures show that the difference in resistance between the malleable and the cast iron beams is greater the shorter the span, and also greater the larger the cross-section. A comparison of the last columns of both tables shows to what extent the flexibility of the material has been altered by the conversion. The deflection of the shorter spans of cast iron were generally not appreciable.

Nos. 5 to 10 inclusive and 16 and 17 had previously been broken as beams and Nos. 11 to 17 inclusive had been in tension. In Nos. 11 to 14 the elastic limit, as determined by the action of the scale beam, did not seem to be reached before rupture, and its general variability is evident from an inspection of the table.

The appearance of the fractured section of this metal varies materially from that of cast iron. Around the outside invariably is found a thin layer of a light gray color from 0.02 to 0.03 inch in thickness. At the center there is generally a core varying in color and size; in color from bluish gray to light gray and in size from nothing to a large proportion of the section, in one case 54 per cent. This core not only varies in size in different bars but changes materially in different parts of the same bar. In one of the larger specimens broken as a 12-inch beam it was about 3 per cent. of the section, and when one of the pieces was again used for a 4-inch span it reached 50 per cent., of the fractured area. It is liable to form a larger proportion of the area of large bars than of small ones, rarely reaching in the smaller pieces tested 20 per cent., and in some cases appearing only as a few light specks on the darker portion of the surrounding material. The larger it is the weaker the iron. Uniformly when a high resistance was obtained the dark gray part between the outer thin layer and the center was large and the core small. That the material near the center of the bar has less tensile resist-

ance is shown conclusively in Table V. and in the beams, as has been remarked in connection with Table IX., a high breaking weight and small core were always found together. It would naturally be assumed, from the method of conversion and from the known effect of the size of the central lighter portion on the physical properties of the malleable iron, that this part consisted of the original cast iron either partly or wholly unconverted. Mr. J. M. Sherrerd, chemist to the Albany and Rensselaer Iron and Steel Co., kindly made some color tests, for combined carbon, of borings made at different distances from the center of one of the inch and a-half square bars. The amount was found to be about the same in the outer thin light layer and in the darker part of the bar between this and the core. In each case it was less than 0.08 of one per cent., practically none. It might seem that there would be a gradual increase in the quantity found going inward from the surface, but the comparisons made showed that, in this case at least, the amount did not grow larger until the core itself was reached, metal taken from its edge giving the same results as that from the exterior of the bar. Tests of material taken from the center gave from 0.44 to 0.31 of one per cent., the first from the finer portions of the borings and the other from the coarser, the difference being probably due to the fact that the parts higher in carbon being harder would be more finely divided in the lathe. Mixtures of the two gave results varying between these limits.

No analyses were made to determine whether the amount of graphitic carbon remained unchanged during the process of conversion.

MEASUREMENT AND FLOW OF WATER IN DITCHES.

By CHAS. E. EMERY, Ph.D.

Written for Van Nostrand's Engineering Magazine.

In the valuable paper by Mr. Aug. J. Bowie, Jr., on the above subject, published in the January number of the Magazine, there is given on page 34 the accepted formula:

$$Q = ac\sqrt{rs},$$

and the notation is described in the following language:

"Q—is the quantity of water which the ditch is capable of carrying in cubic feet per second.

"a—the effective area of cross-section of ditch as constructed originally, in square feet.

"r—the hydraulic mean depth in feet.

"s—the fall of surface in a unit of length.

"c—a coefficient covering all common losses."

An examination of the examples given shows that Mr. Bowie has used in the calculation the *average depth* of the stream, not the "hydraulic mean depth," as stated in the description of the notation. The latter term is a technical one, referring to the area divided by the wetted perimeter. (The words "in feet" are therefore unnecessary.)

Full dimensions are not given from which to calculate r on the correct basis, but, assuming probable proportions for the ditches, it will be found that for the "Texas Creek Branch Ditch," c should equal 109, instead of 59 as stated, and that, for the flume in connection with that ditch, c should equal 180, instead of 59 as stated. For the La Grange main ditch, c should be 116.5, instead of 52 as stated. The context showing plainly the error in the original paper.

The final formula, instead of being

$$Q = 31 \text{ to } 45a\sqrt{rs},$$

should be for the ditches

$$Q = 109 \text{ to } 116.5a\sqrt{rs},$$

and the coefficient be increased to 180 for board flumes.

All the examples are not reworked for want of data, but we trust that Mr. Bowie will supplement his valuable paper with another, giving all the data and the constants on the corrected basis.

ENGINEERING INVENTIONS SINCE 1862.*

By Sir FREDERICK JOSEPH BRAMWELL, F.R.S.

From "Iron."

II.

Next to the subject of motors should have come (had I not been led captive by a balloon) that which I am now about to mention, *i. e.*, the transmission of power. Taking this in the restricted sense of the transmission from a part of the machine to another, commonly with the object of varying velocity, one may point to the increasing use of multiple rope-driving gear, in lieu of belts to inclined spur gear for diminishing noise, and to that kind of frictional gearing to which the name of "nest gearing" has been given. Here the frictional driver being acted on at the two opposing sides, strain is removed from the bearings, and the liability of one of the frictional wheels to stand still, and to be fatally injured by having a flat rubbed upon it is avoided. In that very important branch of transmission, wherein power is taken to long distances, however, we have the development of hydraulic transmission, as is evidenced by the fact of pipes being now laid down through our towns for supplying water under the 700 lbs. on the square inch pressure for motive power; we have companies authorized, if not at work, for laying down pipes to distribute compressed air; we have now, by reason of the improvement in gas engines, the ability to lay on power in every town illuminated by gas, which practically means every town and large village; and we have in New York, and in some other cities of the United States, high-pressure steam, conveyed in mains below the streets, to be used both for power and for heating, for which second purpose, however, it should be remembered, the contents of a gas main are equally available. I will not touch upon other modes, except just to mention the rope system at Shaffhausen; but I think we may take it as clearly established that we are, day by day, becoming more alive to the benefit, where little power is required, or where considerable power is required, but only intermittently, of deriving that power from a central source.

Under the heads of motors and of transmission of power (both of them, it is true, eminently subjects for the civil engineer) I have spoken of water, but there is another way in which water is used, the way with which engineers and the public are more familiar, viz., its employment for the supply of our towns, which I have not as yet mentioned. Except in the magnitude of the work and the excellence of the design, of which the new Liverpool waterworks now in progress may well stand as a typical example, there is not much to say as regards progress in those waterworks which are dependent upon storage. Indeed there is nothing very marked to point to in these twenty-two years in the way of progress in pumping machinery. Having visited the United States and Canada twice within the last two years, and having seen the waste of water that takes place in both those countries (a waste which not only causes the mains to be incapable of keeping up the pressure under the excessive draught, but renders sources of supply insufficient which otherwise would be ample for years to come), I cannot but rejoice at the progress that has been made here in the matter of house fittings, by which waste has been greatly checked, and the risk of contamination that formerly existed with certain closet fittings is ended. This question of house fittings has always been a difficult one, and it becomes impossible to be grappled with by water authorities, such as those in the United States and in Canada, *i. e.*, municipal authorities afraid of offending the voter. We owe it, however, to Mr. Deacon, the engineer of an English municipal authority that it is now possible to deal with the correction of household fittings at a minimum of cost, and, what is equally important with a minimum of annoyance to the householder. By the employment

* Address of Sir Frederick Joseph Bramwell, F. R. S., on his election as President of the Institution of Civil Engineers, January 13th, 1885.

of the waste-water meter, situated under the flagstones of the footway, and controlling a group of houses, it is possible to find out the total waste in the whole of those houses and on the mains supplying them; then to localize that waste so as to attribute its true proportion to the houses that are the offenders, and to attribute the proportion, if any, to the pipes of the suppliers of water. Having ascertained these facts, not only can the suppliers of water cure the defects in their pipe system, but they are enabled to cure the household waste, not by the expensive and annoying process of an inspection of the fittings throughout the whole district, involving the annoyance of, say, ninety householders whose fittings are in perfect order, to detect the ten householders whose fittings are in a reprehensible condition; but by the mere visitation of those ten who are in default, and who cannot, therefore, complain of the visitation. With respect to the purity of the water supply, this, although it relates to water, is so "burning" a question that I fear to touch upon it. I believe that in most of our towns the supply is satisfactory, but I do believe, in spite of the alarm raised by the suggestion of double mains, we might do well in many cases where there is a pure but limited supply, to have a dual system of mains and thus to distribute the pure water separately and for potable purposes. I am not about to hold up the water supply of Paris as an example for us to follow on all points, but the Parisians at least have recognized the expediency of thus sorting their supply when that supply is of varying quality, and when the best of it is limited in quantity. In cases where there appears to be no thoroughly satisfactory source of water the experience of the efficacy of iron purification, as practised at Antwerp, does hold out very considerable promise.

Gas, likewise, has been alluded to under the heads of motors and of transmission of power and of heat, but I now desire to say a few words in connection with it under its more ordinary aspect, that of a distributed illuminant. In the year 1862 the price of ordinary coal gas in London was from four to five shillings per thousand cubic feet; the illuminating power was such that 5 cubic feet of the gas burnt in a specified burner in one hour should give a light equal to twelve sperm candles, each burning 120 grains in the hour. At that time the consumer was, as it was facetiously called, "protected" by restricting the company to a maximum statutory dividend. Obviously, so soon as this dividend was earned, all incentive to improvement was removed. One of the few cases in which recent legislation relating to private companies supplying public wants can meet with the approval of the political economist, was that which a few years ago first recognized it would be well for the private company and for the public that the ordinary incentive of increased profit for increased exertion should remain, and that introduced in certain gas undertakings the "sliding scale." This provided for a normal price, and for a maximum dividend, but allowed the company to ratably increase this dividend in accordance with a decrease in price below the normal. Under this wise legislation, sixteen-candle gas is sold in London for as little as two shillings and tenpence per thousand cubic feet. But illuminating gas has to be considered by the engineer under two distinct heads: one, its manufacture and distribution; the other, its utilization. This last, it is true, is but to a small extent in the hands of those engineers who have the charge of the first. Considerable progress has, however, been made of late in illumination, largely, it is true, due to a greater liberality on the part of lighting authorities, and the use thereunder of multiple burners in street lanterns, but to a considerable extent due to that much more to be desired improvement, whereby a greater amount of light is obtained from the same volume of gas. The regenerative gas-burners, and other modes of burning, into which time will not permit me to enter, promise to largely increase (it is said, even to more than double) the candle-power per cubic foot of gas burnt. Such improvement as this is undoubtedly of great moment, not only on the score of economy, but on the sanitary ground of diminishing the amount of products of combustion poured into a room in relation to the light therein afforded. It need hardly be mentioned that the decrease in cost and the increase in profits are largely due to the application of chemistry to this manufacture, by

which application the former nuisance-creating by-products have been turned into sources of revenue and into fertilizers for our fields. I have also, in the most cursory manner, mentioned gas as a means of distributing heat; but a word should be said about those valuable improvements in gas-furnaces—I do not mean the Siemens furnace—which have enabled coal-gas to be applied to the melting of even very refractory metals, by means of a most inexpensive plant. Nor have I spoken of those other applications, where, either burnt with coke (it may be of the very coal from which the gas itself was derived), or caused to raise incombustible bodies to incandescence, it forms the cheerful and smokeless substitute for a smoky coal fire, or is utilized for the purpose of domestic cookery. In this latter case, however, if absolute cleanliness and ventilation are not preserved, there will (as the unhappy traveler, compelled to temporarily sojourn in the "limited" hotels of the present day finds to his cost) be one universal dirty gas-oven flavor impressed upon all his food, be it the homely leg of mutton or the lordly haunch of venison.

Although it is quite certain that the first suggestion for using liquid fuel (notably tar, to aid in heating gas-retorts) must date long before 1862, yet the great development of the mineral oil industries since that date has led (and especially in Russia, in whose territory such enormous yields of oil are afforded) to the employment of this material as a fuel in furnaces and in steam boilers. Next to the infinitely divisible forms of gaseous and of liquid fuel comes, as I have said elsewhere, the dust fuel introduced by Mr. Crampton. In the use of any of these three forms, regularity of mechanical supply is a condition involved; and any one of these three, therefore, irrespective of all other considerations, is desirable because it is a means of dispensing with that most unsatisfactory form of labor—"stoking," dispensing also with the production of smoke, and with the diminution of maximum effect attendant on the hand-feeding of coals, where the condition of the fuel in the grate and its temperature must be ever varying. Having regard to these advantages which are to be obtained in using oil, and to the cheapness of the material in Russia, one is not surprised to find that there are lines of steamers on the Caspian worked entirely by liquid fuel, and that the same kind of fuel is used to fire the locomotives in many districts.

I have mentioned the improvement in small furnaces worked by illuminating gas; but I am not entitled to bring within my period the regenerative gas furnace, that great invention made by our lamented friend Sir William Siemens, with whose name in this matter should be coupled that of his brother, Mr. Frederick Siemens. This latter gentleman, by a course of study, has recently discovered, and it is an interesting scientific fact, that so far from the heating power of the flame being increased by its confinement within narrow chambers, and by its being brought into contact with the material to be operated upon, such arrangements only diminish that power; and he has further found that this discovery can be usefully applied in practice by keeping the roof of a regenerative gas furnace at such a height above the hearth on which the materials to be heated lie, that the flame can traverse from one side of the furnace to the other, free of contact with the roof above, or with the materials below. Very excellent economic effects and a high heat, it is stated, have been obtained by causing the outgoing products of combustion to give up their heat to the incoming cold fuel. I have seen such furnaces in operation making steel by the hearth process, and it is the fact that the chimney has been without a trace of red glow within it.

The natural oils which are used as fuel, and to which I have referred, are rarely employed in their crude state as obtained from the wells; but they all undergo more or less refining before use. There is another natural fuel, however, which has been discovered in America, and within the last few years largely utilized—this is the gas obtained from wells in a manner similar to that in which the oil is obtained. It is a marsh gas of high calorific power, and is in certain parts of the United States being used very largely for domestic heating, for the heating of furnaces of every description, including those for the manufacture of plate-glass and of steel; it is also being employed for the manufacture of lamp or carbon black, and for the carbon points for electric lighting. It is stated that within a radius of 20 miles from the town of Pittsburgh, taken

as a center, there are twenty-five wells, each producing 3,000,000 cubic feet per twenty-four hours, and that the produce of the whole of the wells at present opened up is 100,000,000 cubic feet of gas per day. To my mind this is one of the most perfect fuels which can be imagined. It requires no preparation, but can be and is, used in the same state as that in which it issues under a high pressure from the wells; it can be mechanically controlled with the greatest nicety, and when properly burnt is entirely free from smoke or similar defects. When employed in the Siemens regenerative furnace, the producer, which is necessary where coal is used, is entirely dispensed with.

Probably there is no function of the engineer in which the public feel their interest to be so immediate as when he is engaged in supplying to them their food. Prior to 1862 it is true that steam ploughing and various cultivating and reaping machines were in existence; but they have been much developed since, and if the English farmer is to be saved while growing grain, it will be by reason of his availing himself of the labors of the engineer. Unhappily for the farmer, he has not the monopoly of the engineer's services, the products of whose skill are as fully appreciated for the cultivation of the enormous corn districts of the far west by the farmers there as they are in England. Again, unhappily for our farmers, the engineer, by his railways and by his improved steamships, renders it possible for the grain grown in the United States and in Canada to find its way to our markets at a cost for freight so trifling as not to equal that which, a few years ago, would have been paid for transit from one part of England to another. It would not be right to pass away from improvements in agricultural engineering without referring to that which is a distinctive novelty since 1862. I mean the fast-becoming general combination with the reaping machine of string sheaf-binding apparatus. I am afraid I cannot claim for the engineer that recent introduction the "silo." He is rapidly turning his attention to the improvement of the details, and is showing how mechanical appliances can be advantageously used in connection with them. By the aid of silos our grass crops may be saved in the green form, notwithstanding wet and unpropitious seasons; but those who still prefer sweet and sound hay may hope that the engineer will devise some practical mode of artificial drying, and thus enable them to obtain it even in the absence of the sun, and may also hope that the adoption of similar means will save our grain crops, although the harvest may be followed by steady and continued rain. But a question may arise, whether, except for horse feed, we need trouble ourselves about silos or hay, having regard to the fact of the great development since 1862 in refrigerating machinery, which renders possible the importation of frozen meat from Australia, and from other countries. I hope for the sake of the English farmer that there will still be many who will be prepared to pay for English grown beef and mutton, and for real milk and real butter, and that they will not be tempted by cheapness to substitute milk of condensation and butter of oleo-margarine. But I hear the poor farmers are now threatened by a flood of steamboat-transported milk from Holland. While on the question of food the temptation is great upon me to refer to the wonderful improvements that have been made in "milling' since the year 1862; but I must refrain from this and from all other remarks upon the question of food, except to remind you that if the providing of food is one of the great social problems of the present day, another is how to get rid of sewage. This latter problem, however, has been so fully dealt with by my immediate predecessor, Sir Joseph Bazalgette, as to leave me nothing to say.

There are two other most important subjects involving large commercial interests, and in one of the subjects at all events, great modern invention, upon which, fortunately, I need not say one word, as in respect of the first of these—electricity—I can refer you to the volume of lectures delivered here in 1883; and in respect of the second—tramways—I can refer you to the papers which, with the discussion upon them, have already occupied three evenings of this session. I see that our allotted time is already exceeded, and I am thus compelled to leave unsaid much which I should have liked to have told you, touching many things which almost every one of you must remember (each in his own special line of engineering) as being of general interest,

and novel since 1862—railway brakes and signals, for instance; but the subject upon which I have undertaken to speak is so vast, that even with the severe limitation which, as I have stated in the earlier portion of my address, I had imposed upon myself, I find omission is inevitable. Just a few words (and they shall be very few) about our institution. You have done me the honor to elect me your president; and I trust it is unnecessary to assure you that during my term of office I will do everything in my power to uphold the dignity, the honor, the usefulness, and the prestige of the institution; but my efforts alone will not be sufficient; I must ask you—each one of you—to help me, as failing this help the president is powerless. If each one of you, in his own way, works to advance our general interests by attending at our meetings, by bringing his quota of information on the subject which is under discussion to enrich our proceedings, by taking care that in speaking to give this information, the time of the institution shall not be wasted, either by bald repetition of platitudes or by fine oratory, and by remembering that his endeavor should be to add to the general knowledge in the simplest and most concise way possible to him, then I hope we shall be able to say at the termination of my period of office that the institution has not retrograded, but that the ends and aim I am sure we all have in view have been materially enhanced. As I have already said, I will do all that lies in my power in the future as I have done in the past to arrive at such a consummation, and I must ask you—all of you—to assist me, feeling sure as I do that such assistance will be cheerfully and gladly rendered.

FACTS NOT GENERALLY KNOWN CONCERNING ELECTRICAL INVENTIONS.

By J. S. BEEMAN, M. S. T. E.

From "The Engineer."

The history of the transmission of electric energy by high-tensioned currents, its storage and distribution, is very interesting, as showing the development of an idea which has for long exercised a certain fascination for practical men, viz., the transfer of the energy of waste natural sources of force to localities where it can be utilized. As these localities may be situated at a considerable distance from the source of force, the capital invested in the collecting, transmitting, and distributing apparatus must of necessity be the ruling factor in the case from a commercial point of view, and therefore the economy to be effected by the application of some system for storing the energy and changing its tension to such as is found by experience to be the most expedient, is of great importance. Having in view the improvements in secondary batteries which have already been published, and those which we have still a right to expect, the day may not be far distant when the ideas that have been promulgated regarding such a system, applied to the distribution of electricity, will take concrete form. The various steps by which it has attained its present position, and been brought into the ranks of practically applied natural sciences, form the subject of this article. One of the earliest notices formulating such a design appeared in an article in the *Chemical News* in the year 1862, and ran as follows;—"Sitting by the seashore a few days since, we could not help noticing the vast reservoir of mechanical power existing in the ocean. We do not refer to the noisy dash of the waves as they break upon the beach, but to the infinitely mightier although silent and progressive energy exerted in the gradual rise and fall of the tides. By means of appropriate machinery connected with this tidal movement, any kind of work could be readily performed. Water could be pumped or air compressed to any desired extent, so as to accumulate power for future use, or for transport to distant stations. Light of surpassing splendor could be generated by means of magneto-

electric machines; and with a very little extension of ingenuity, every lighthouse on the coast could be illuminated with sun-like brilliancy and with absolutely no expenditure of fuel; the very same mechanical power of the ocean, which in its brute force would dash the helpless vessel to pieces against the rocks, being bound and coerced like the genii in Eastern tales, and transformed by man's intellect into a luminous beacon to warn the mariner against the approach of danger." This idea of utilizing the tidal power was, in 1871, actually embodied in a patent by Ferdinando Tommasi, for the working of which it was proposed to form a company. The apparatus, called the flux-motor, was a machine worked by the action of the tides, by which compressed air was to be delivered to customers through a network of pipes, on lines somewhat similar to those employed for the supply of gas. The idea was certainly somewhat unique, but, as far as can be ascertained, has never been practically tried; had it been carried to a practical commercial issue we should by this time have been in possession of a very cheap source of power for the production of electric energy. The possible application of this great natural force, by enclosing tidal waters just before the ebb sets in, and working motors through their release, has, however, been shown, in most cases, to be probably less remunerative than the utilization of the land so enclosed for other purposes. In 1877 public attention was drawn to this question by the late Sir W. Siemens in his opening presidential address to the Iron and Steel Institute. He then stated that the energy of the Falls of Niagara might be made available by the then known mechanical means—though undoubtedly in a very wasteful manner—saying, to quote his own words, "Time will probably reveal to us effectual means of carrying power to great distances, but I cannot refrain from alluding to one which is, in my opinion, worthy of consideration—namely, the electrical conductor. Suppose water power to be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance through a large metallic conductor, and then be made to impart motion to electro-magnetic engines, and ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod, 3in. in diameter, would be capable of transmitting 1000-horse power a distance of, say, thirty miles; an amount sufficient to supply a quarter of a million candle-power, which would suffice to illuminate a moderately sized town." It is of historical interest that in the following year—1878—Sir Wm. Armstrong practically applied this method for the utilization of natural forces in lighting his house at Craigside during the night, and working his lathe and saw bench during the day, by power transmitted through a wire from a waterfall nearly a mile distant from his mansion. In October, 1878, Mr. St. George Lane Fox patented his system for electric distribution by means of secondary batteries, and as far as information is obtainable, this is the first public mention of secondary batteries being employed in such a system, although, as has been shown in a previous article, they had been patented at an earlier date as regulators to the circuit. Mr. Lane Fox's system is an extension of the idea of regulation, and it is worthy of passing note that at this period high-tensioned current dynamos, such as we are now accustomed to—the Brush, for instance—were practically unknown, the Brush patent not then having been published in this country. In November of the same year, a French engineer patented an invention, entitled "Improved means of Transmitting Electricity to Great Distances." Although his views and ideas were erroneous, the patent is interesting as showing that in ventive talent was directed towards the subject of this paper, and because of the crude ideas contained in it as to the character of dynamic electricity. In December, 1878, Edison patented a system showing duplicate sets of batteries, one set being in the discharging circuit whilst the other could be in the charging circuit—there was practically no difference of tension in the two circuits. An interesting part in the patent was the apparatus whereby the sets of batteries, when fully charged, were cut out of the charging circuit; this was effected by utilizing the gas given off to lift a diaphragm which actuated a switch or

contact breaker. In May, 1879, Sir William Thomson gave evidence before the Select Committee of the House of Commons on lighting by electricity, saying, in reference to the utilization of the energy of the Falls of Niagara for the purpose of generating electricity, and in answer to question No. 1799, "There is no limit to the application of it on a general scale. It might do all the work that can be done by steam engines;" he qualified this, and explained how it could be done in a later part of his evidence, by stating, in answer to question No. 1903, that the current sent along the wire would be used to turn electro-magneto machines, which current would be produced by magneto-electric machines. In October, 1879, Luke took out a patent for Houston and Thomson, wherein they showed means by which the tension of the discharging circuit might be raised far in excess of the tension of the current produced by the generator, this being accomplished by charging the batteries in sections and discharging them in series. The special feature of the patent bearing on one subject is contained in the twenty-second claim, and is the method described of bringing a dynamo-electric machine into circuit with a storage battery by first bringing the machine to its normal condition of working by the interposition in its circuit of, first, a normal working resistance, and afterwards of the secondary battery. In March, 1881, Professor Perry, whilst lecturing at the Society of Arts, said that for the future development of the transmission and distribution of electric energy it would be necessary to use electric machines of great electro-motive force. During the lecture, and afterwards in the discussion, reference was made to Professor Ayrton's paper read at the British Association meeting, held the previous year at Sheffield wherein he pointed out, in a full and comprehensive way, how the energy of the Falls of Niagara might, theoretically speaking, be conveyed to New York, along a single ordinary telegraph wire. The system, which was based on theoretical grounds only, and was dependent on exceptionally good insulation, was explained thus: Only a small amount of current would be conveyed along the wire, but it would have an enormous potential; and although the difference of potential between the ends of the telegraph wire would be nearly *nil*, yet the difference of potential at all points along the route, between the line wire and the earth, would be extremely large, so that much energy could be put in at the generating place—viz., Niagara—and a nearly equal amount would be delivered at the motor place—viz., New York. Thus, through the current being so very small, the waste of energy in electric friction would be very slight. In April, St. George Lane Fox, when lecturing before the Society of Telegraph Engineers, carried the system a step further by expounding a scheme whereby the energy transmitted under high potentials could be safely and usefully applied. He is reported to have used the following words: "Electricity could be conveyed from a very great distance at an enormous electro-motive force, which electro-motive force could be reduced to any extent by means of a system of condensers, or of secondary batteries, and a suitable arrangement of commutators working automatically, so as to suit the requirements for distribution." Mr. Crompton, during the discussion, said: "As to the use of the secondary or reservoir batteries to act as a store of electrical energy, it is one of those things much talked of, but never yet practically carried out. M. de Meritens told me a few days since that a secondary battery had been recently brought out in France, which gave surprising results; five or six times as much energy can be stored in it as in the Plante battery." About May 16th appeared a letter in the *Times* announcing the arrival of the above secondary battery, called, after its inventor, the Faure accumulator. On May 18th Mr. Alexander Siemens lectured at the Society of Arts, upon "Electric Railways and Transmission of Power by Electricity." He described a number of ways in which high potential currents could be utilized. He drew attention to large central stations fitted with powerful steam engines and dynamos supplying current to secondary batteries which would kep the electric energy stored until required for use. On June 6th appeared the celebrated letter of Sir Wm. Thomson anent the Faure secondary battery, in which he stated that the Faure accumulator always kept charged from

the engine by the house supply wire, with a proper automatic stop to check the supply when the accumulator is full, will be always ready at any hour of the day or night to give whatever light is required." On the 9th he further wrote, when alluding to credit due to the late Sir William Siemens as the originator of the idea of utilizing the Niagara Falls as the natural and proper chief motor for the whole of the North American Continent. "Under practically realizable conditions of intensity, a copper wire of ½ in. diameter would suffice to take 26,500 horse-power from water-wheels driven by the Fall—losing only 20 per cent. on the way—to yield 21,000 horse-power at a distance of 300 British statute miles; the prime cost of the copper, amounting to £60,000, or less than £3 per horse-power actually yielded at the distant station." Early in September he, when delivering his opening address as President of the Physical Science Section of the British Association at the York meeting, went still further, and polnted out that through the introduction of accumulators much smaller conductors could be used than were anticipated by the late Sir William Siemens in 1877, and further, that the necessarily high potential current employed to transmit the current long distances could be converted at its center of distribution into such a low potential current as should be desired for the several purposes at the points of consumption of the electric energy. He went into fuller details regarding the contents of the letter alluded to above, stating that until he heard of Faure's inventions he could only think of step-down dynamos at a main receiving station, to take the energy direct from the electric main with its 64,000 volts, and supply it by secondary 200-volt dynamos through proper distributing wires to the houses and factories and other places, where it could be used for every suitable purpose requiring power. Now, the thing could be done much more economically, and with much greater facility and regularity, by keeping, say, 40,000 secondary battery cells always being charged direct from the supply main, and applying a methodical system of removing sets of 100, and placing them on the town supply circuits, while other sets of 100 were being regularly introduced into the great battery that is being charged. He further described and showed an automatic apparatus which he had designed and constructed to break and make the circuit between the battery and the dynamo. On the 24th of September, Duprez and Carpentier obtained a patent, wherein was described a system very similar, but, of course, giving more definite details of apparatus to be employed than did Sir William Thomson in the address referred to above. They referred to an automatic galvanometer which actuated a commutator or switch, thus causing the connection of the discharging circuit to be always in contact with a very constant supply of electricity. In November, Professor Sylvanus Thompson, at a lecture at the Society of Arts, stated that we had in the tidal basin of the Avon enough energy to light Bristol, and in the channel of the Severn there was sufficient power—if only one-tenth were conserved in accumulators—to drive every loom spindle and axle in Great Britain. By this time the inventive public was thoroughly aroused, and the records of the patent office show that the details of the working out of the above system has received great attention. Nothing new has, however, been shown affecting the principle. Last month news reached this country that the Bell Telephone Company has two wires connected with the Niagara Falls, by means of which the Exchange at Buffalo has recently been operated. As an experiment, a generator was placed on the paper mills of Quimby & Co., at Niagara Falls, and the machinery connected with twenty miles of wire, the result being a success. The various attempts that have been made in this and other countries, notably France, with systems worked on the line herein set forth, are practical evidence of the value of the foresighted idea of the late Sir William Siemens.

AT a meeting of the Edinburgh Royal Society, Prof. Tait read a paper by Mr. W. F. Petrie, on the old English mile. The old mile was longer than the present, and consisted of 5,000 feet of 13 inches. It seemed to be identical with the old French mile. The furlong had no connection, originally, with the mile, which was modified to suit the former.

THE APPROPRIATE ORNAMENTATION OF WORKS IN IRON.*

By G. RICHARDS JULIAN, A.R.I.B.A.

From "Iron."

When your able honorary secretary did me the honor to invite me to read a paper at one of your meetings of this session, I was for a few moments doubtful as to whether there was any subject on which I had a right, without presumption, to address you. I, however, ventured to think that the appropriate ornamentation of works in iron, although not a new subject, either to my mind or to yours, was one on which I might offer some suggestions worthy of your consideration. I think that I shall not be considered overbold if I say that this is a problem which still awaits solution, and that, if it is to be solved at all, it must be done either by the united efforts of the engineer and the architect or by the development of a new species of workers, who might be denominated artist-engineers. Some of my professional brethren will at once tell me that every architect is, or should be, an artist engineer, and such a name doubtless defined the architect when engineering was a much less complex business than it has now become. I am not one of those who regret the division of labor which has taken the designing of great bridges, gigantic shed roofs, and similar works out of the hands of the architect; and, to explain my position, let me glance at the work which is left to us. The architect has to make himself acquainted with the history of his art from the earliest times, with its developments in various countries and under differing circumstances, and with the characteristic forms and ornaments associated with those developments. He has to be familiar with the arrangements necessary to be considered in planning domestic buildings, from the cottage to the palace, ecclesiastical structures of all sorts, warehouses and manufactories, banks and offices, hospitals and town halls, hotels and public offices, &c., &c., *ad infinitum*. And in planning these various buildings he must not only arrange them conveniently and economically, but ever keep before him the æsthetic effects which should be produced, dignity or magnificence, or picturesqueness, as the case may be. He must use his materials not only scientifically but artistically; he must keep out the wet, and keep down the damp; he must provide for warming and ventilation, and for those sanitary matters, in which if he fails he will now-a-days soon meet with the reprobation which he will deserve. In his practice he will have to deal with questions of rights of light and air, with the requirements of building acts and local regulations, with dilapidations and valuations, with estimates, and, alas! with the builder's little bill for extra work. He must keep abreast of new discoveries and inventions, as they may affect his work, and he must be an authority on wall papers and other decorative materials, and often, and very properly, on furniture. Add to this several other matters which would take too much time to enumerate, and I think you will agree with me that there is enough for any one man's lifetime without his being called upon to master "strains under moving loads," and so on. Life *is* short, although art and science are long, and I do not believe that, with the continual additions made to our store of knowledge, it is possible for one man to be both a good architect and a good engineer. I will not attempt the unnecessary task of detailing to you the engineer's daily work, but will only say that, busy with his calculations of loads and strains, with his railroads and other great works of utility, he does not, as a rule, find much time to devote to the study of the principles that lie at the root of artistic design, a study which has, too, formed no part of his professional education; and this is my excuse for coming before you to-night. The application of artistic principles to the design of the iron supports, both vertical and horizontal, now so very commonly used in building, has been both delayed and deliberately avoided. The principal reason of this is doubtless the very rapid spread of

* Paper read before the Civil and Mechanical Engineers' Society on January 14, 1885.

the use of iron, and especially of cast iron, for structural purposes; the designing has been done in a hurry, and all the real thought has been bestowed on the scientific—the utilitarian—side of the question. The engineer has been too busy with experiments, as to the best practical forms and proportions, to give due consideration to artistic treatment, and the architect, educated in the use of other materials more pliable for his purposes, has been too apt to avoid structural ironwork, dismissing it with the summary remark that it is "an inartistic material," and, when compelled to use it, concealing it as much as possible. These remarks, of course, apply only (so far as wrought iron is concerned) to its use for structural purposes; for ornamental purposes, the gates and grilles, the well-covers, hinges, vanes, and finials, the lock-plates and numerous other applications of wrought iron in the middle ages and in the sixteenth and seventeenth centuries, show us truthful, beautiful and skillful design and workmanship, in perfect harmony with the nature and capabilities of the material used. Cast iron is the more serious offender against good taste, as although there are in existence, in the farm houses of Sussex and in other places, panels forming the backs of fireplaces, dating from the seventeenth century, of excellent design, and pretending to be nothing but what they really are, yet, in more recent ornamental works, such as railings and gates, cast iron too often imitates the forms either of stone or of wrought iron, and but too rarely is treated honestly and truthfully, as a material cast, and not fashioned or wrought.

It is, however, principally to structural works in iron that I wish to direct your attention, and I think we shall all be agreed that it is now quite time that the appropriate mode of ornamentation of such works should be, if possible, defined; that we must be prepared more and more to use iron in construction of all buildings of any great size, is, I think, a fact that is evident to all; and to prove that some sort of ornamentation must be applied to that ironwork, needs but little argument, since man, so soon as he takes the first step towards civilization, commences to apply ornament to all his surroundings, and the character and the quality of the ornament continue to advance with the subsequent steps, until in the highest and most refined states of society, we find it developed into the most perfect forms of what is called fine art. The desire for ornament, in fact, seems to be as much a part of human nature as the desire for food; and it is certainly to be hoped that future ages shall not be obliged to say of this that it could do everything with iron except ornament it appropriately. Many definitions of architecture have been proposed, but the one which I consider the best is, that it is "the useful art of building elevated to a fine art," and directly engineering attempts to do anything more than to erect structures of simple utility, unadorned in any way, directly a curve is introduced, or a moulding is added for the purpose of pleasing the eye, it become amenable to the same artistic laws, and must, or should, conform to the same æsthetic principles which rule and govern architectural design; in short, the engineer who desires to make the structure which he erects ornamental as well as useful, ranges himself at once among the artist workers of the world, and should, therefore, endeavor to make his ornamental work truly artistic. The expression of the sense of beauty, which is inherent in man, is the aim of all the fine arts; and every mode of its expression, whether it be poetry or music, painting or sculpture, or architecture, is subject to positive laws, such as those of harmony and proportion, and to what I may call negative laws, such as the avoidance of falsehood, of coarseness, of tricks, and of vulgarity. Our work is artistic, so far as it obeys these various laws, and ornament then becomes appropriate to the material by means of which we attempt to give expression to the sense of the beautiful.

Let me state a few of the laws which appear to me to apply more especially to our subject, a consideration of which may, I hope, point to the direction in which lies the solution of our problem. First, as to the avoidance of falsehood; any work to be beautiful must be truthful; it must appear to be what it really is. A construction of iron must not be made to simulate one of stone or of wood; cast iron must not be so treated as to look like wrought iron. To say this seems almost unnecessary, it appears so

self-evident; yet, how often—to cite instances which come to one's recollection at once—do we see the cast-iron coping and balustrade of a bridge imitating, as well as they can, the common forms of a stone parapet, and then carefully painted to make the deception as complete as possible; or how often in cast-iron gates and railings are false bands and rivet heads to be found. Such treatments of material not only excite disgust in anyone with even the most elementary knowledge of art, but exhibit a melancholy poverty of thought and want of artistic inventive power in the people who perpetrate them. It may be objected that some forms of stone architecture have originated in imitations of wooden construction, as seen in rock-hewn tombs in Lycia and in Egypt, and in the details of the entablature of the Grecian Doric order; the first attempts at using a new material would naturally, in the infancy of art, be imitative, but before any true style of architecture arrived at maturity such conscious imitations had faded, never to be renewed except in periods of decadence. But this truthfulness must go a step further. The forms of ornamentation appropriate to one material must not be imitated in another, the character and capabilities of which are different. We see how a recognition of the capabilities of the respective materials has produced the refined and delicate forms of Greek detail executed in hard marble, and the boldly undercut moulding and foliage of the best Gothic work executed in comparatively coarse and soft stone. We have also opportunities of seeing how unsatisfactory is the attempt to reproduce the Greek detail in the coarser material, when most of the refinement vanishes; and, on the other hand, deeply-worked carving or moulding in marble always produces an unpleasant feeling of labor lost, of an expenditure of energy which is disproportionate to the artistic result obtained. I may summarize this by saying that ornament to be appropriate must be the natural outcome of the character and capabilities of the material employed, and such as can be executed without undue expenditure of labor; and that ornament should be made, so far as possible, to tell its history truthfully; that which is cast should not imitate forms appropriate to carving or to forging, and *vice versa*.

Another application of this law is: That construction, where it is shown or indicated, must be that which actually contributes to the support of the structure. We need not, of course, show all the construction but when anything is shown that looks like construction, it must not be a sham, constructed merely for ornament; this condemns the cast-iron arches and spandrels sometimes filled in, quite uselessly, under a girder, and many similar arrangements with which we are all familiar. All this points to the conclusion that, to obtain appropriate ornamentation, we must be guided by the best and simplest method of manipulating the material with which we are dealing. We must not start with any preconceived ideas as to forms and details, obtained from the treatment of other materials, but allow the scientific use of each to suggest its artistic forms.

Works in iron have been subject to many severe criticisms when considered in relation to proportion. Proportion is, of course, one of the main elements of beauty in architectural compositions; many buildings, which are almost devoid of ornament, satisfy the eye by such an arrangement of their parts as is generally recognized as being in good proportion; and, on the other hand, no amount of decoration will compensate for the absence of this quality. Proportion finds its expression in the relation of voids to solids, and in the forms and relative heights and breadths of both; in the preservation of a proper scale between the details of ornamentation and the features to which it is applied; in such a combination of supported parts and supports as shall give *apparent* as well as real stability, and in the amount and distribution of light and shade. The adverse criticisms to which I referred have been based on the fact that most of our ideas on proportion have been derived from the observation of buildings, the materials of which require, for structural purposes, relatively larger supports than is the case with those erected in iron. I venture to think that these critics have allowed this fact to lead them astray when they tell us that "true architecture does not admit iron as a constructive ma-

terial"; * they are even inconsistent, for they do not themselves desire a wooden post to be of the same proportion as a Doric column; and they are satisfied not only with the Doric proportions, but with those of the Gothic cathedrals, although the material used in both is practically the same. It will take some little time, doubtless, to enable our eyes to be satisfied that the supports in an iron structure are strong enough for their work. To some extent this has already been accomplished, and when the process is complete we shall doubtless hear (other things being satisfactory), praises of the elegant lightness and soaring beauty of such buildings, similar to those which are lavished on the slender piers and groined vaults of the middle ages. I mention these criticisms because I feel that much harm has been already done by them, and more will follow, unless it be understood that they do not receive the assent of all artists and art students. Iron will continue its onward march, even though a Ruskin stand in the way, and if those who work in iron are continually told that they are dealing with an inartistic and an unarchitectural material, how can any improvement be expected? I believe that the time is coming when the idea of an alliance between iron construction and fine art will fail to provoke a smile, even upon the faces of the most thoughtless. Use your iron, then, in the most scientific way. Find your proportions, first of all, by calculations which tell you what is necessary, but do not forget that where there is more than one way of arranging the parts (and when is there not?) you should not rest satisfied until that one has been attained which combines the greatest utility with that which best satisfies the cultivated eye; above all, do not play any tricks, let the apparent construction be the real construction everywhere, and the world will soon learn to see the beauty of the proportions.

That ornamentation may be harmonious, we must take care that no one part of a design be too rich or too bold for the others; this does not, of course, prevent us from making use of the element of contrast by arranging our decoration about certain features; in fact a study of harmonious contrast will lead us to emphasize the construction by means of the ornament, as we find it done in all the great works of the past. In all works of art, refinement must be present, if the result is to be of a high order; not merely the absence of coarseness and clumsiness, but the actual presence of some sort of refinement in delicacy of details, modulation of shadow, and all the little things that show careful study, painstaking attention, cultivated taste, and the determination to be satisfied with nothing short of the best that the circumstances permit. I have dwelt at some length on these principles of art, because in the present day, when we have lost the habit of instinctive artistic workmanship, owing to the various revivals and changes of fashion from which we have suffered, it is only by constant attention to first principles that we can hope to keep on the right path. The great mistake in the revival of one style after another has been that, instead of the principles which guided the architects of the past to such great successes, having been studied, the results have been reproduced in a more or less slavish manner; but that phase is, I hope, passing, and I look to the development of an original and artistic treatment of iron to assist in the movement. Let us now endeavor to arrive at some conclusions as to the manner in which these principles may be applied.

Before coming to the subject of exposed or visible ironwork, I should like to say a few words on the covering of such structural ironwork as is necessarily concealed, I mean in buildings which it is desired to render fireproof. In these cases it is now generally accepted as an axiom "that no building can be fireproof unless all constructive ironwork is protected." And here arises a strong temptation, in protecting the construction with concrete or terra-cotta, to assume that one is at liberty to imitate the forms of stonework, and to revert to old and well-established proportions. The argument commonly advanced is, that in such a case your ironwork is the skeleton only, and that as in the human body, the bones are clothed with a beautiful form unlike themselves, we may clothe our iron skeleton in any beautiful form that we like; but the analogy, as commonly applied, will not hold good; to cover the iron

* Ruskin's *Seven Lamps.*

construction with an imitation of stone construction is to cover a skeleton of iron —which is supposed to be ugly—with a sham skeleton proper to another body —which is held to be beautiful—instead of surrounding the bones with a beautiful exterior that shall still indicate their forms and proportions. The application of our principles to such cases will lead us to indicate the forms of our construction; if, for instance we have to protect a stanchion of the H form, its general outline being a square or an oblong, suggests a clothing of similar form; if of the + pattern, the plan of its covering should preserve the cruciform shape in its faces, while the angles might be filled with splays or moldings. Such treatments are truthful, exhibit thoughtful design, and better preserve the proportions of the constructive forms. A circular column would naturally have a circular encasement, but, again, the proportion should not be destroyed, and direct imitation of stone columns should be avoided as far as possible. Girders and cantilevers should be dealt with in the same manner. The faces of the casing can, of course, be decorated with paneling, banding, and so on, in any way suitable to the material used for the purpose, and to its position. We thus see that, even where our ironwork is hidden, attention to artistic principles will guide us to original and appropriate ornamentation.

Coming now to exposed or visible ironwork, let us first glance at the natural treatment of wrought iron. We have here a material which can be rolled, hammered and forged, bent, twisted, or perforated, built up, or framed and jointed in various ways; the webs of plate girders and of cantilevers can be ornamented by perforation, while in built-up girders of the lattice or the Warren kind the actual construction often gives an ornamental form, the various parts—the lattices, for instance—might often be made decorative by being fashioned or cut, especially where they are formed from plates rather than angle or tee irons, and the joints should receive more consideration, artistically, than is usually bestowed upon them. Although no unnecessary features are to be added for the mere sake of ornament, a few pounds' weight of iron added to the necessary features, to allow of their being made ornamental as well as useful, is perfectly legitimate. The application of hammered scroll work to some of the parts of built-up structures, if not overdone, is an evident means of obtaining beauty and giving interest to the work. In large roofs or in bridges I look to the further development of the combination of cast with wrought iron, as opening a wide field for ornamental treatment. When we turn to cast iron we are dealing with a material which, as used for structural purposes, is but little older than the century in which we live, and for the treatment of which there is no direct precedent. Here we have a material which, as its name indicates, is cast in a mold. and which, consequently, shares with other materials which are similarly treated, the liability—owing to the cheapness with which such decoration may be produced—to be ornamented with imitations of carved and hand-wrought work. There are, however, difficulties of manufacture connected with the casting of iron, especially in large pieces for structural purposes, which will guide and limit us in seeking for the appropriate ornamentation of it. One principal point is, that in designing for cast iron, the material must as far as possible be of uniform thickness throughout, otherwise we shall have cracks and flaws in the process of cooling; this shows at once that our ornament should avoid anything like undercut carving, any system of design that calls for projecting knobs or blocks, which cannot be easily cored; it also shows that for the same reason our moldings and surface ornament should be of slight projection, and without deep sinkings or hollows, unless the back of the casting can be made to follow the face surface without affecting the strength, and without adding undue difficulty to the process of manufacture.

In designing a column or stanchion for execution in cast iron, we will consider first its form or plan; the circular hollow form gives of course the most economical use of material, but has certain disadvantages. You cannot get at the interior for examination or for painting, and you cannot easily see that you have necessary uniform thickness of material throughout; for these reasons I am inclined to prefer the

stanchion as being better suited to the character of the material. If, however, a hollow column be used, other forms than the circle may be adopted, such as the square with rounded or molded angles, the regular octagon with or without projecting faces, the irregular octagon—that is, one with four main faces and four subordinate ones which may be molded—and others which will suggest themselves to you. The advantages of these forms of plan are, less likelihood of imitation of stone details, greater appearance of stability, owing to the actual increase in size, as well as to the apparent increase when such forms are seen in perspective, and the advantage which flat faces offer for the proper treatment of the capitals. The last reason also suggests that where circular columns are adopted, slightly projecting, vertical fillets should be added, carrying down the lines of the brackets at the top, and giving an appearance of rigidity to the shaft. In detached stanchions the cross-with-equal-arms plan seems the best in ordinary circumstances, but often the form of the stanchion should, I venture to think, be suggested by the superstructure which it has to carry. In dealing with these supports in elevation, I will speak first of the capital, or top; a capital, in the ordinary sense, as applied to a stone column, is not wanted at all; such a capital is a separate block of stone placed on the shaft, and ornamented by molding or carving cut into its solid mass; these have, however, formed the types from which cast-iron capitals have been generally derived, and most unsatisfactory we all know their effect to be; for instance, we see a Corinthian capital, or some approach to one, in such a position; now from association of ideas we expect to find, below a Corinthian capital, a column of the usual Corinthian proportion, that is, about ten diameters high, including the cap and base; so, by putting this capital, we challenge comparison between the proportion of our iron column and the old stone one, and the consequence is that the iron is denounced as a wretched, skinny abortion, or in some other equally uncomplimentary phrase.

In designing the top of a column or a stanchion for pure utility, as in some position where it is not to be seen, what do you do? You put at the top a projecting flange, somewhat like what we architects call the abacus, but with projection enough to allow of the proper bolting of the girder, or whatever else is to be carried; you then arrange brackets, cast on to carry this top flange; let us treat our ornamental capitals on the same lines and we shall satisfy our artistic principles, and not set agoing any invidious comparisons between our works and those of the masons.

I have ventured to prepare a sheet of illustrations, showing how this may be attempted. I do not, of course, put these designs of mine forward as being perfect, or claim for them anything more than that they are attempts to grapple with the problem of uniting to sensible and natural construction such ornament as is appropriate to the nature of the material. I have everywhere used what I will call the bracket form of capital, and shown how it may be applied to different kinds of columns and stanchions. In dealing with the shafts all the edges may well be molded in a very simple and refined manner; this is almost suggested by the difficulty of obtaining absolute squareness in section, when you have to withdraw a casting from a mold; the surfaces may be paneled and the panels enriched; but all sinkings should, of course, be very slight, not only for the practical reason to which I have already referred, but because this again suggests the character of the material and its method of manufacture. Flutes running the entire length of the column should certainly be avoided; it is difficult to get true lines in them; they make a small column look smaller and taller than it really is, and they are imitations of a familiar form of stone ornament. Horizontal bands around the columns, however, will always tend to increase the apparent diameter, and so are valuable. Short lengths of fluting between these bands, and in such positions as the top of the columns, where they add apparent stiffness and power to support the weight, may be used, but they should be small and sharp in section, instead of wide and flat, as in stonework, as they then suggest the hardness of the material. In the cross-shaped stanchion I have introduced small horizontal stiffeners, or flanges, and endeavored to treat them

ornamentally. Although these only add slightly to the actual strength, they are very valuable artistically, as seeming to bind the whole together. They also serve the same purpose as the bands on the columns by adding apparent breadth. When foliated ornament is used, although we should not imitate stone or wood carving, we can hardly expect to invent an entirely new system of foliage for our purpose, and it is not only quite legitimate to turn to the works of the past for suggestions, but it is our duty to do so, otherwise we throw away a part of our heritage.

In what direction should we make our investigations? We réquire low-relief, and that sharpness and crispness of outline which should accompany it if it is to be effective; this we shall find in the early Greek work, which was executed in a hard material, in the Byzantine work which inherited the traditions of the Greek, and for surface and paneled decoration—in much of the early Renaissance detail; learning from these beautiful works of former ages we may, without servile imitation, obtain in time a modified and consistent system of iron foliated ornament. One word more under this head: our foliated ornament must be conventional; naturalesque decoration is seldom satisfactory in effect when applied to any part of a structure which appears to be doing work, that is, carrying a load or resisting a thrust, and never, unless it comes direct from the hand of the artist, in the form of carving or of painting. The remarks which I have made as to moldings generally apply, of course, to the ornamental bases of columns. These should have very slight projection, and be in no way imitations of the ordinary stone base with its deep hollows and bold rounds. The use of stanchions will get over all this difficulty, as each face would have its own projecting moldings, possibly connected by a horizontal band. In cantilevers or large brackets, modeled or perforated ornamentation will be used in the spandrel panels, which the forms of these features will suggest; such ornament might be arranged with projection producing the effect on one side and sinkings on the other, so that the thickness of the whole might be fairly uniform in all its parts. Cantilevers should never be cast hollow, but always with a visible web of the necessary thickness only.

In America, whole fronts of business premises are sometimes constructed of iron, and in many cases in our own city, where every inch of window space is of importance, the same system might be adopted with advantage. Such fronts, to be artistically good, will need very careful designing; we must cast ourselves loose from old traditions, and work in the spirit which I have tried to indicate to you. There must be no great hollow sham cornices and strings carried on hollow, closely-spaced cantilevers, such as I have read of in accounts of the American examples. With a sheet of drawing paper and time to spare, I think that I might work out something that should obey the laws of art, but until I should have done that, I am afraid that I can hardly launch into a detailed description of such a front; I should certainly start with honest stanchions and girders, and where I had any surfaces to cover, I think that wrought-iron plates with ornamentally-cut edges, or cast-iron modeled panels would be the line I should first try.

With these few suggestions I must leave the subject to you, only saying further that we must not be disheartened at any want of success, but remember that it took a long, long time, and much patient and loving work, to evolve beautiful and appropriate ornament in other materials.

> What good gift have my brothers, but it came
> From search and strife, and loving sacrifice.*

I once heard the following sentiment expressed by a speaker at a meeting of the Royal Institute of British Architects: "I suppose that if the question of iron were brought before the Institution of Civil Engineers, and anyone spoke of treating the material beautifully, it would raise a laugh;" more than once as I sat writing this paper this sentence rose before me like a grizzly specter shaking a finger of warning, but that my opinion does not coincide with that, is proved by the fact that I have dared to come before you to-night, and to speak of the possible connection of structural ironwork with true beauty. If I have suc-

* Edwin Arnold's *Light of Asia.*

ceeded in throwing out one suggestion that may set any of you in the way of giving to your works that appropriate ornamentation, which will add to them greater human interest and artistic vitality, I am more than satisfied.

ON THE REAL VALUE OF LUBRICANTS AND ON THE CORRECT METHOD OF COMPARING PRICES.

By ROBERT H. THURSTON, Mem. Am. Soc. C. E.

From Transactions of the American Society of Civil Engineers.

THE real value of any lubricant is a quantity which seldom has any direct relation to its market price, and depends not only upon the intrinsic qualities of the unguent itself, but upon the economical conditions under which it is to be used. It is dependent to a greater extent upon the magnitude and cost of power than upon the expense of its purchase or preparation for use by the consumer. The correct method of comparing prices, from the user's standpoint, is not one involving merely a determination of the properties of the material as a reducer of friction, and the true value of the oil is not simply proportional to its endurance and its power of reducing lost work; it includes a study of the method by which it reduces the total expenses of lessening friction, and the extent to which total expense for power is reduced by such reduction of work wasted by friction. The usual systems of comparison are entirely wrong, and are only justifiable by the fact that hitherto it has been impracticable to obtain the data required for the establishment of a correct method. This difficulty no longer exists, and every intelligent purchaser of lubricants is coming to see that he may often effect enormous economies by the careful study of the variation of the total cost of lubricant and of waste power.

The total cost of the lost work in machinery includes two distinct items—the cost of lubricant, and the cost of doing the work of overcoming friction of the lubricated surfaces. Of these, the latter is usually enormously the greater, and it is at once seen that a saving in cost of lubricant is of slight importance in comparison with a saving of equal proportion in the reduction of the cost of the power demanded to overcome friction, and which is thus wasted. A dollar expended in the substitution of good oil for one of lower grade may save a hundred by the reduction of the waste of fuel and other expenses of power production. Such expenses include fuel, salaries, interest on capital invested in motive power, taxes and insurance on the driving machinery, boilers and building, and other and minor costs, which every proprietor can readily estimate with fairly accurate figures, if not with perfect satisfaction to himself.* The total cost of steam power thus foots up to about $100 per horse-power per annum in New York City, and to a minimum of, perhaps, $50 under more favorable conditions. Water-power often costs considerably less, although the cost of dams, reservoirs and machinery is large.

If, in any case, we call the total expense per hour K, the cost of the lubricant on the journal k, the quantity used q, the total cost of power per horse-power per hour k', and the amount of power used in overcoming friction of lubricated surfaces U, the total expense chargeable to "lost work" will be

$$K = kq + k'U \qquad (1)$$

The work done in overcoming friction U is proportional to the mean pressure on the lubricated surfaces P, to the speed of relative motion of rubbing surfaces V, to the time taken for comparison t, and to the magnitude of the coefficient of friction f. Thus we may write

$$K = kq + bf \qquad (2)$$

in which b is a constant, the value of which, k' P V t, is easily ascertained in any given case, and the calculation of the cost of friction is then readily made.

* "Friction and Lubrication," R. H. Thurston: New York, 1879; § 75, p. 200. "Friction and Lost Work in Machinery and Millwork," R. H. Thurston: New York 1885; Chapter VIII.

Where two oils are to be compared, to determine the economy to be secured by the substitution of the one for the other, the values of q and of f, and the cost per gallon, k, of each will be known, and the two values of K thus obtained will exhibit the relative economy of their use. If K is the same for the two, it is a matter of indifference which is used; if K is greater in one case than in the other, that oil is the more economical which gives the lower value, even though it may cost more per gallon, and may require to be more freely used than the other. Thus, suppose, for the two cases we have

$$K_1 = k_1 q_1 + b f_1 \; ; \; K_2 = k_2 q_2 + b f_2.$$

If these two values of K were equal, $K_1 = K_2$, and the gain by purchasing of the second oil is just compensated by the loss due to increased demand for power to overcome the increased friction, and

$$k_1 q_1 - k_2 q_2 = b(f_1 - f_2) \qquad (3)$$

$$k_2 = \frac{k_1 q_1 + b(f_1 - f_2)}{q_2}. \qquad (4)$$

Any price paid for the second oil, *delivered on the journal*, less than k_2 gives a profit; any greater price produces loss. This last equation is thus a criterion by which to determine what price, k_2, may be paid for any oil proposed to be substituted for the first oil, costing $k_1 q_1$ per hour.

Where the same quantity is used of each, as may be the case frequently, $q_2 = q_1$, and

$$k_2 = \frac{b}{q_1}(f_1 - f_2) + k_1 \qquad (5)$$

The question sometimes arises whether it is better to use a larger quantity of a certain oil already in use; in this case $k_2 = k_1$, and the quantity allowable without loss is

$$q_2 = \frac{b}{k_1}(f_1 - f_2) + q_1 \qquad (6)$$

Where the relative endurance, and the relative values of the coefficient of friction are determined by experiments made under the conditions of proposed use, if e and h represent the two ratios, since the quantity used will be inversely as the endurance, and the power wasted will be directly as the coefficients of friction,

$$k_2 = e k_1 + b e f_1 \frac{1-h}{q_1}; \qquad (7)$$

and this expression becomes the criterion of values.

Instead of taking the time as one hour, and the unit of power as the horse-power, it may be convenient to adopt other units. Thus, on railroads the costs are measured by the cost of oil and of power per train mile, and

$$K = kq + df \qquad (8)$$

in which q is the quantity of oil used per mile, and df is the cost of power for the same distance. Also, as a criterion,

$$k_1 q_1 - k_2 q_2 = d(f_2 - f_1) \; ; \; k^2 = \frac{k_1 q_1 + d(f_1 - f_2)}{q_2} \qquad (9)$$

In illustration of the application of these principles, take the following cases:

(1.) The proprietor of a large machine shop informs me that he finds the total expense of power to be nearly $100 per horse-power per annum, of which power one-half is estimated to be expended in doing work wasted in friction; that he uses 0.02 gallon per hour of good lubricants, costing an average of $0.50 per gallon. The mean coefficient of friction is judged to be about 0.05. The value of b (eq. 2) is found to be 0.6 horse-power, or 30 for 50 horse-power; then

$$K_1 = 0.01 + 1.50 = \$1.51.$$

Supposing it be proposed to substitute for the oil in use one which costs but $0.25 per gallon, and of which 0.03 is required per hour, and that the coefficient of friction with the cheaper oil is $f_2 = 0.06$, then

$$K_2 = 0.0075 + 1.80 = \$1.80\tfrac{3}{4},$$

and a gain of one-quarter of a cent. per hour, or $7.50 per year, is effected at the expense of a loss in cost of power of 30 cents an hour, or $900 per year, and a net loss of $892.50.

(2.) A cotton mill, using 200 horse-power, in work of overcoming friction of lubricated surfaces, uses 0.7 gallon of oil per hour, at $0.70 per gallon; it is proposed to substitute an oil costing $0.40, and of which one gallon per hour will be required to do the work, while the coefficient of friction will rise from an average of 0.10 to 0.12. Taking b at 60, as before:

$$K_1 = 0.49 + 12.00 = \$12.49;$$

$$K_2 = 0.40 + 14.40 = \$14.80.$$

A gain in expense for oil amounting 9 cents per hour, or $270 per year, produces a loss in cost of power of $2.40 per hour, or $7,200 per year, assuming 3,000 working hours per annum. The net loss is $6,930, *i.e.*, nearly 30 times the profit on the oil account. This is not an unusual or an extraordinary case, as matters are now going on in the business.

(3.) A railroad train requires 1 cent's worth of oil per mile, and costs 10 cents per mile for power expended in friction, using a good oil, costing 50 cents per gallon, at the rate of 0.02 gallon per mile, with a mean coefficient of friction of 1 per cent. It is proposed to change, using an oil costing but 25 cents, at the rate of 0.03 gallon per mile, and obtaining a coefficient of $f_2 = 0.015$; then

$$df_1 = 0.10;\ d = 10 \text{ (eq. 8)};$$
$$K_1 = 0.01 + 0.10 = \$0.11;$$
$$K_2 = 0.0075 + 0.15 = \$0.15.$$

In this case a gain of one-quarter of a cent per train-mile in cost of oil brings about a loss of 4 cents—sixteen times as much—in increased train resistance.

Using the equations given as criteria of values (eq. 4, 6, 9), we find the estimated value of k_2 to be, in the three cases given, respectively: $-\$19$, $-\$2$, and $+16\frac{2}{3}$ cents, nearly, for the cases as taken. That is to say, the proprietor of the machine shop will lose $19, nearly, on every gallon of the proposed oil that he may use; the owners of the cotton mill will lose about $2 on every gallon of the inferior oil that they may purchase; while the railroad will lose money, unless it can get the second oil for $16\frac{2}{3}$ cents.

But suppose, in further illustration, that it is found possible, by increasing the supply of oil in the case of the machine shop, to reduce the mean coefficient of friction to 0.02, by using four times as much of the cheaper oil as was at first thought advisable. Applying our criterion to this case we get (eq. 4):

$$k_2 = 0.03 + 0.60 = \$0.63,$$

and a gain is effected of nearly two-thirds the original cost of lubrication. An expenditure of $60 gives a profit of about fifty times that amount.

It must not be assumed that these figures are more than rough approximations to fact; for it is difficult to obtain exact values of the quantities involved, and especially of the true mean value of f; but they are sufficiently correct to answer as illustrations of the principles involved, and are near enough to the truth to give a fair idea of the magnitude of the losses which are each day met in consequence of the practice of the system of false economy now generally practiced in the purchase of lubricants.

The values assumed for the coefficients of friction are probably fairly representative of those found in common practice. The experiments made by the writer show that, under ordinary conditions of every-day practice, the value for mechanism working under as light pressures as are met with in spinning frames, for example, different oils will give values from 0.10 to 0.25; under the usual pressures of heavy mill shafting, the figures range from 0 5 to 0.10; with pressures of greater intensity, such as are met in the steam engine and under railroad axle bearings, it often varies, using different lubricants, from about 0.01 up to 0.025, the first value being given by the best oils and the second by heavy greases. Under the exceptionally high pressures and at the speed of rubbing reached on the crank-pins of some steam engine (500 to 1,000 pounds per square inch, 35 to 70 kgs. per sq. cm.), f may fall to one-half the last given values. In endurance, the same variations are met with. The endurance decreases as pressures increase, and is twice as great with the best oils as with others of good reputation. The market prices of oils have no relation to these relations of quality. The best oils for any given purpose may be either more costly or cheaper than others less well fitted for the work. In some cases prices are made in the most arbitrary manner.* Sperm, lard, olive, and some few standard grades of mineral oils probably have fair and well-settled values; as a rule, however, the price of a mineral or of a mixed oil is no guide to selection.

Should time permit, and statistics prove to be attainable, the writer will endeavor to develop this subject more completely.

* The writer has been informed of one case in which the dealer purchased an oil for 12¼ cents per gallon, gave it a trade name and sold it, unchanged, at $1.25. It was worth that amount, however, if compared with other oils in the market that may have cost the "maker" much more.

A STANDARD METHOD OF STEAM-BOILER TRIALS.

Report of Committee to the American Society of Mechanical Engineers.

From Advanced Copy of Transactions of the American Society of Mechanical Engineers.

II.

Appendix to Code.

I. OBJECT OF THE TEST.

In preparing for and conducting trials of steam boilers, the specific object of the proposed trial should be clearly defined and steadily kept in view.

1. If it be to determine the efficiency of a given style of boiler or of boiler setting under normal conditions, the boiler, brick-work, grates, dampers, flues, pipes, in short, the whole apparatus, should be carefully examined and accurately described, and any variation from a normal condition should be remedied if possible, and if irremediable, clearly described and pointed out.

2. If it be to ascertain the condition of a given boiler or set of boilers with a view to the improvement of whatever may be faulty, the conditions actually existing should be accurately observed and clearly described.

3. If the object be to determine the relative value of two or more kinds of coal, or the actual value of any kind, exact equality of conditions should be maintained if possible, or where that is not practicable, all variations should be duly allowed for.

4. Only one variable should be allowed to enter into the problem; or, since the entire exclusion of disturbing variations cannot usually be effected, they should be kept as closely as possible within narrow limits, and allowed for with all possible accuracy. J. C. H.

II. GENERAL OBSERVATIONS.

All observations are to be made by the expert, either personally or by his assistants. No statement of any kind is to be received from the owner or persons in charge of the boiler. All possibility of anything that would falsify the results must be closely guarded against; all pipes not used must be taken away or blank flanges inserted.

The two great points that are to be determined in every test of a steam-boiler, whatever the special and precise purpose of such test may be, are, the pounds of fuel burned, and the pounds of water evaporated.

To arrive at these we need to know, first, the pounds of fuel put into the furnace, and second, the pounds of water fed into the boiler.

To ascertain these facts with certainty is the fundamental requisite in all cases. The possibility of an error in either of these respects throws doubt upon all the results or indications of the test. The coal supplied to the furnace and the water fed to the boiler should, therefore, each be ascertained in a manner that proves its own correctness and excludes doubt.

All tests of this nature are properly regarded with suspicion. I often myself read of tests and results that I put no faith in, and the same must be true of every one who is experienced in this matter. I am therefore strenuous on this point, that a system of firing and a system of measuring the feed water should be employed that will prove the correctness of the record, and if errors are made, will clearly expose them.

If possible the steam generated should be condensed by passing it through a surface condenser, where it is cooled by a strong current of water in a closed chamber. By this means the number of thermal units added may be ascertained with precision.

A boiler test cannot be conducted properly when it is complicated by being combined with an engine test. C. T. P.

III. PRECAUTIONS TO BE OBSERVED IN MAKING A BOILER TEST.

It should be steadily kept in mind that the principal observations to be made are the quantities of coal consumed and of water evaporated. If these quantities are ascertained accurately, and the conditions made the same at the beginning and end of the test, the most important

requisites of a boiler trial will be secured. Other observations have their value both for scientific and practical purposes, but are in most cases subsidiary.

Boiler tests are often undertaken with insufficient apparatus and assistance. It is possible for a single person to test one boiler or even several in a battery, but it requires a great deal of labor to do so, and in many cases such person would be so fatigued as to be liable to make a simple error, vitiating the results. He would moreover at no time be able to give proper oversight to the test, so as to prevent accidental or unauthorized interferences. It is very desirable, in fact almost indispensable, that an assistant be detailed to weigh the coal, and another to weigh or measure the water; if calorimeter tests are to be undertaken still another assistant should be provided. The engineer in charge is then left free to oversee the work of all, and relieve either temporarily when necessary. Engineers are frequently called upon to make boiler trials in connection with parties whose interests are antagonistic to a fair test, and frequently voluntary assistance of busy-bodies is likely to produce errors in the results. It is therefore essential to have trustworthy assistants, and those of sufficient caliber not to be confused by interested parties, who will frequently endeavor in the most plausible manner to make out that a certain measure of coal has been already tallied, or that a certain tank of water has not been tallied.

In the first engine trials at the American Institute Exhibition (1869), in the Centennial boiler trials (1876), and since in private trials respecting performance of boilers as between the contractor and purchaser, the writer has arranged for both interests to take the data at the same moment, with instructions, if agreement could not be had, that the difference be at once referred to him.

In weighing the coal, the barrow or vessel used should be balanced on a scale and then filled to a certain definite weight. The laborer will soon learn to fill a vessel to the same weight within a few pounds by counting the number of shovels thrown in, when the change of a lump or two, to or from a small box alongside the scale will balance it.

The water may be measured in one tank by filling it to one mark and pumping down to another, but this involves stopping the pump when filling the tank, thereby failing to maintain uniformity of conditions. Two tanks arranged so that each can be filled and emptied alternately are much better. A still better plan is to have a settling tank to pump from and a measuring tank which is emptied into it, and this plan is improved by setting the measuring tank on a scale, and actually weighing the water. For large operations three tanks are necessary: a lower tank to pump from and two measuring tanks, one of which is filling while the other is being emptied. The writer has made several double measuring tanks with a horizontal section like the figure "8," there being a partition between the two tanks lower than the rim of the tanks. Water is conducted at will in either of the two tanks by a pipe swinging over the partition. One tank is allowed to fill until the water in it overflows into the other (which has been emptied and the cock shut), when the filling pipe is shifted into the empty tank, and as soon as the water level subsides in the full one, the water in that tank is allowed to flow out, the cock shut before the other tank is filled, and the operation repeated.

A simple tally should never be trusted. Nothing seems more reliable to an inexperienced observer than to mark 1, 2, 3, 4, with a diagonal cross mark for 5; but when there are waits of several minutes, between the marks, and several operations performed after a tally is made, there will be confusion in the mind whether or not the tally has been actually made. The tallies both of weights of coal and of tanks of water, should be written on separate lines, the time noted opposite each, and the records always made at the beginning or termination of some particular operation; for instance, in weighing coal at the time only when the barrel or bucket is dumped on the fire-room floor. It is desirable to have a number of coincident records of coal and water throughout the trial, so that in case of accident it may be held to have ended at one of such times. The uniformity of the operations may also be tested in this way from time to time. For this reason it will be found convenient to fire from a wheelbarrow set on a scale

and to have a float or water-gauge connected with the tank from which the water is pumped; by which means the coal and water used may, in an evident way, be ascertained for any desired interval.

As to calorimeter tests, note from the special article on that subject (Appendix XVII.) that the results are liable to be untrustworthy simply from an improper connection to the boiler. Scales and thermometers very finely graduated are desirable, but if they cannot be procured, good instruments with medium graduations carefully standardized may be employed, when if the observer will take the precaution mentioned in the appended article of the writer on calorimeter experiments, and simply make each record according to his best judgment at the time, the average of the results will be substantially accurate, although the several experiments may disagree somewhat with each other. C. E. E.

IV. WEIGHING THE COAL.

Where practicable, a box consisting of sides, back and bottom, capable of holding 500 pounds of coal for each boiler having twenty-five square feet fire-grate area, and in proportion for larger grates, should be placed on scales conveniently located for shoveling from it upon the fire grate.

The exact time of weighing each charge of say 500 pounds, should be noted, and the net weight, whatever it be, set down. [The box should be balanced by a fixed counterpoise, so that the readings of the scale beam may be net pounds of coal.]

On the instant of closing the fire door after each firing, the weight should be taken and the exact time noted as well as the weight. The box should be completely emptied each time, and the accuracy of the counterpoise observed, and, if necessary, adjusted. The differences of weight at each firing will give the several quantities fired; the differences of time will give the intervals in minutes and seconds between successive firings; and the differences of time between the successive charges—500 pounds, more or less—on the scales, will afford a check on the record of the firing. A chart or diagram should be plotted from the figures, which will clearly show the degree of regularity with which firing has been carried on, and reveal any omission or error. J. C. H.

V. WEIGHING THE COAL.

I would recommend that on a test no coal be brought into the furnace room except as follows:

A barrow to be employed, and be loaded each time at the coal pile with an equal amount, say 600 lbs. of coal, weighed on platform scales at the pile. The time when it is thus wheeled into the furnace-room to be noted. The barrow to be wheeled upon another platform scale before the furnace for the following purpose:

In separate columns, the times of charging the furnace to be noted, and the reading of the scales after each charging. The coal to be shoveled from the barrow directly into the furnace.

Now, here the log would show at once, by the great inequality of the intervals, if a barrow load of coal had been added or omitted, and the weights charged on the fire would check the barrow loads, and should also show the rate of firing.

No other coal being convenient to the furnace, reasonable watching will give assurance that none is surreptitiously added to the fire. C. T. P.

VI. WEIGHING THE WATER.

The best way is to have two tanks capable of holding 1,200 to 1,800 pounds, say 20 to 30 cubic feet, or two weighing tanks and one feeding tank, 144 to 216 gallons, each placed on a pair of scales, to be filled and emptied alternately. To avoid suspicion of leakage of stop-cocks, it is better to draw out the water by a flexible pipe or suction hose put alternately into the two tanks. The time of each weighing of each tank, to be designated as tank No. 1 and tank No. 2, should be accurately noted, and a method of checking the weighings by a diagram or chart as in respect to the coal, should be adopted. J. C. H.

VII. MEASURING THE FEED-WATER.

I would recommend that on all tests of any magnitude the water be fed to the boilers from a single tank of known capacity. That the tank be always filled so as to overflow, while the feed pump is

stopped, and also the communication to it is closed.

That the inlet pipe shall terminate above the tank so that its orifice is always visible. That after the supply has been shut off, and the overflow has ceased, the communication to the feed pump be opened and the pump be started. That the water be drawn down to a point that is determined by a line on a graduated rod attached to a float that has been well painted so as not to absorb the water; and that then the pump be stopped, communication with it be closed, and the tank be refilled.

The time of starting the pump each time to be carefully noted.

The regularity of the intervals would leave no room for doubt as to the number of tanks that had been emptied. The watch of opposite interests would insure the accuracy of the line at which the pump is stopped each time, and at which the test was closed. C. T. P.

VIII. KEEPING TIME OF OBSERVATIONS.

All time-keepers should be set at the start, and compared at the close; a gong should be used to give a signal for all observations designed to be synchronous and isochronous, in order that such observations may be conveniently arranged. J. C. H.

IX. RECORDING STEAM GAUGE.

A good recording steam gauge, Edson's or other, carefully adjusted, should be used and accurately compared with the steam gauge at stated intervals. Such an automatic record, nicely integrated, is a good check on the record of the steam gauges. J. C. H.

X. AIR THERMOMETERS.

The air thermometer is the best instrument for taking the temperature of flues, smoke boxes, etc., from 300° to 700° or 750° F. These instruments cost but a trifle, $3 to $5, and can be made anywhere, by any competent expert, or by any one of his assistants under his directions, and can be relied on for ordinary temperatures, say 60° to 90°, up to any temperature which glass will bear without deformation. Ordinary machine-divided paper scales can be used with them. The great point is to deprive the interior of the bulb and tube of all moisture, and to fill the bulb and the upper half of the leg of the inverted siphon connected with the bulb, with dry air. (Appendix XI.). The expansion of dry air is practically uniform for all useful ranges of temperature, and its volume is directly proportioned to its temperature from absolute zero, say 461.2° F. below zero F., equal to 493.2° F. below the temperature of melting ice, to which the conventional zero of the air thermometer, at the accurately observed and noted temperature of the air when the mercury in the two legs of the inverted siphon is exactly level—the tubes being exactly vertical—can be conveniently referred. For instance, if the temperature of the air when the mercury in the two legs is level, be 73.8° F., add to this 461.2°, and we have 541.0° F. absolute, as the true absolute temperature corresponding to our zero. Double this temperature—1082° F. absolute (equal to 1082°−461.2° =620.8° F. above zero F.), would double the volume of the air; but the volume being nearly constant—since the capacity of the tube may generally be disregarded, a difference of level will be produced in the height of the mercury in the two legs of the inverted siphon exactly equal to the height of the mercury column in a mercurial barometer at the time. No correction for capillarity is required, since the negative capillarity is equal in the two legs. No correction for temperture is required, unless the temperature of the *mercury* in the air thermometer is higher than that of the mercury column of the barometer. If there is an observable difference, it must be corrected for, at the rate of 0.0001 per degree F.

There should be at least two of these air thermometers, three would be safer, in readiness for each test, to avoid disappointment by accident. The legs of inverted siphon must be vertical, but the tube from the upper end of the leg to the bulb may be straight, or bent to any angle.

For the determination of the heat of flue gases, this instrument is indispensable, up to the limit of the softening of glass; but since no flue will always, or even usually, contain volumes of gas of equal temperature throughout at the same instant, at least two tubes of gas pipe, welded up at the lower end, and

filled with mercury, should be placed in opposite sides of the flue, near the air thermometer, for observing the differences with chemical thermometers graduated on the glass. Sir Wm. Thomson highly commends thermometers incased in hermetically sealed glass tubes, with scales graduated on paper for use up to a point below the temperature required to scorch the paper. Dampness being excluded by the glass case, the paper scales are of unchangeable length, and the graduations and figures are very distinct and legible. J. C. H.

XI. DESCRIPTION OF AN AIR THERMOMETER OF CONSTANT VOLUME (AFTER REGNAULT) AND OF THE MODE OF CONSTRUCTING AND USING THE SAME.

This instrument may be made in many forms, and of materials of several kinds—metals, or glass, or metal and glass. A simple, inexpensive, and convenient form* consists of a U tube of about three-eighths of an inch external diameter, and about one-sixteenth of an inch caliber, or a little less; having a short leg about 39 inches long, and the other leg longer by 12 inches or more; the latter surmounted by a bulb blown out of the tube, $1\frac{5}{8}$ inches in diameter, $6\frac{5}{8}$ inches in extreme length, and 5 inches long in its straight, cylindrical portion.

The two legs, or branches, of the U, are two inches apart between centers.

They are separate tubes, each one bent to a right angle, by a curve of short radius, ground square and true at the ends which are to meet, and hermetically united by a short coupling of rubber tubing, firmly bound on each with wire.

In blowing the bulb, a small, short tube, about $\frac{1}{16}$ inch in caliber, and 2 or 3 inches long, is formed on top for use, making the instrument—to be sealed by fusion when it is done.

Having formed the U tube by uniting its branches, the next thing to be done is to dessicate its interior perfectly and to fill it with dry air. For this purpose it is put in any convenient position—reclining, probably—a piece of rubber tubing is secured to the small tube on top of the bulb and connected with a U tube about 6 inches long in its branches, and $\frac{5}{8}$ inch or $\frac{3}{4}$ inch in diameter, filled with dry lumps of chloride of calcium and surrounded by crushed ice, to lower its temperature, and the temperature of the air passing through it to about 32° F., at which point air parts with a larger portion of its moisture than at any higher temperature.

An aspirator is now connected by a piece of rubber tube, with the open end at the short branch of the instrument, and a stream of air is drawn in through the chloride of calcium tube and discharged by the aspirator.

A simple and efficient form of aspirator is merely a piece of $\frac{1}{4}$-inch gas-pipe, bent, when hot, into three or four sharp zig-zags, with an inlet at its upper extremity for water, and at its side for air. A stream of water flowing through the zig-zag tube draws air in at the side orifice, and the air becoming entangled with the water, flows off with it—its place being supplied through the chloride of calcium tube and the U tube of the thermometer. This operation can be carried out conveniently in any office or other room supplied with a flow of water and a set wash-basin; and once arranged, requires only so much attention as to see that it remains undisturbed.

When the tube is completely dessicated (in so far as air at 32° F. will give up its moisture to chloride of calcium), which will be in about four or five hours, shut off the water, bend over the rubber tube connecting the calcium-chloride tube with the bulb, or, another rubber tube connected with the outer branch of the calcium-chloride tube, so as to prevent any mixture of moist air with the dry air in the bulb and U tube, and lay the instrument on its side in such a manner that the longer branch shall slope from the bulb down to the rubber coupling, and that the shorter branch shall also slope from the rubber coupling down to the extremity of this branch, which should be kept closed by the finger until it is immersed in mercury to prevent the admixture of moist air. If the mercury is in a wide, shallow dish, like a plate or a saucer, the sloping end of the branch may be immersed in it sufficiently; or a short piece of glass tube coupled on *in advance*, when preparations were made for the desiccating

* Constructed and brought to my notice by Fred. W. Prentiss. Originally devised by Regnault.—J.C.H.

process, may be held down in the mercury. Then apply the lips to the calcium-chloride tube or to the rubber tube connected therewith, and, by inspiration of breath, draw out air from the bulb until the mercury, forced into the shorter branch, fills it, and shows just beyond the rubber coupling in the lower end of the long branch. Then pinch the rubber tube, set the instrument upright (keeping the open end of the shorter branch closed with the finger until it is upright). See that the branch tubes are exactly vertical; carefully relieve the pinched rubber tube, so that air may escape, until the surface of the mercury in the two branches is exactly level; then pinch the rubber tube and fuse and seal the small glass tube into a little button on top of the bulb. Now hang up an accurate chemical thermometer, graduated on the tube, close beside the bulb, until this thermometer and the bulb and the dry air inside of it are certain to have come to a common temperature, and read and note this temperature; and make a distinct and permanent mark on the back-board of the instrument, at the level of the mercury in the two branches. This back-board may be 4 or 5 inches wide, $\frac{1}{2}$ to $\frac{5}{8}$ inch thick, and about as long as the shorter branch, and the tube may be secured to it by little staples of annealed iron wires, going around (*i. e.* over) the tube and through holes in the back-board; and twisted together at the back. A bit of soft leather at the staple, between the board and the tube, will form a secure bed for the tube, and obviate danger of breaking. Such staples are indicated on the drawing, at *c*, *c*, *c*. There may be two such staples at the bottom, passing over the rubber coupling, to further aid in keeping the two parts (branches) of the U tube in proper position. At the same time that the temperature is noted, note also the height of the mercury column of a barometer. On the air thermometer, hanging in my office, the notes are:

"Temperature 81.5° F.

"Barometer, Hg, 31.03 in."

Attached scales complete the instrument. For these, engine-divided paper scales will answer; and they may be graduated to inches and tenths of inches, as I have indicated, or to millimeters.

Since the instrument is to be used chiefly or wholly for temperatures above any atmospheric temperature at which it may be set, the scale on the long leg need not exceed much above, nor that on the short leg much below, the level line; but a $\frac{1}{2}$ inch, or an inch may be worth while, if the instrument is set as high as 80° F., for convenience of comparison with ordinary thermometers.

FOR USING THE INSTRUMENT:

Let t_1 = temperature at which thermometer is set.

t_2 = temperature sought from observation.

$\pm h$ = difference of level of mercury, when the thermometer was set; + when mercury is highest in short leg; − when mercury is highest in long leg; $h = o$, when mercury is level at the noted temperature when the thermometer is set.

Let b_1 = mercury column of barometer when the thermometer was set.

b_2 = mercury column of barometer at the time of observation.

$\pm h_2$ = difference of level of mercury in the two branches when observed:

Then,

$$t_2 = \left\{ (461.2 + t^1) \frac{(b_2 \pm h_2)}{(b_1 \pm h_1)} \right\} - 461.2$$

If made of good hard glass, this instrument is safe at 800° F., say 426⅔° C., and will not be very likely to fail at under 850° F., say 454⅔° C.

The part of the tube below the bulb BI, may be of any convenient length, and may be bent as at F, to any angle to suit requirements of location.

J. C. H.

XII. PYROMETER.

So far as known to me the only way to measure temperatures between 600° or 700° F., or above the range of the air thermometer, and 2500° or 2700° F., or up to the melting point of commercial platinum, is by the platinum water pyrometer.

One form of this pyrometer is described in the journal of the Franklin Institute, Vol. 84, pp. 169 and 252, September and October, 1882. J. C. H.

XIII. PYROMETER.

The temperature of the escaping gases should be ascertained, not by pyrometers, but by means of certified mercury thermometers introduced at a number of different points in the same plane transverse to the flue. The velocity of the current should be ascertained at each of these points. The distance of the transverse plane of observation from the boiler should be noted. C. T. P.

XIV. DRAFT GAUGE.

Some instruments for indicating the force of chimney draft:

a. A bent glass tube filled with water.
b. A bent tube with two fluids.
c. An incased aneroid.
d. A differential pressure gauge.

The incased aneroid, having inches of mercury indicated by spaces of about two inches, divided to $\frac{1}{100}$, answers well. The case is air-tight, and by means of a three-way cock the interior of the case may be put alternately in communication with the external air and with any flue into which a suitable pipe is inserted.

The differential pressure gauge was devised and put to use at the Massachusetts Institute of Technology, and similar instruments should be manufactured for sale. I will not attempt to describe it further than to say that a column of water in a glass tube, acting on a small diaphragm, balances the weight of the movable parts when a large diaphragm is in equilibrium of pressure. Now if this large diaphragm have chimney pressure on the inner side, and atmospheric pressure on the outside, the difference of pressure will be shown by a rise of water in the glass tube to a height proportioned to the ratio of the areas of the small and large diaphragm.

Draft should be measured in different parts of the flue, in order to detect infiltration of air through cracks in the brick-work and through the brick-work itself. J. C. H.

XV. DRAFT GAUGE.

Mr. C. P. Higgins, of Philadelphia, has recently made the draft gauge shown in the sketch. The gauge is filled with water above the level of the horizontal tube, so as to leave a bubble of air about half an inch long near one end of the horizontal tube when the water is level in the side tubes. The inside diameter,

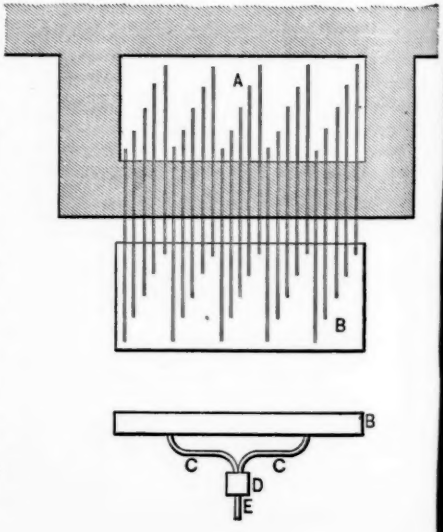
of the two vertical tubes being the same, say half an inch, and the diameter of the horizontal tube $\frac{1}{8}$ of an inch, a draft equal to one inch of water, or which will cause the difference in the level of the two tubes to be one inch, will cause the bubble to move eight inches in the horizontal tube.

The readings of the ordinary U tube draft gauge are thus multiplied by 8, with the additional advantage that the position of the air bubble can be read more accurately than the difference of level in the ordinary gauge. The scale applied to the horizontal tube requires to be standardized for the ratio of areas of the small and large tubes and for irregularities in the caliber of tubes.

W. K.

XVI. SAMPLING FLUE GASES.

Very great diversities in the composition of flue gases often exist in the same



flue at the same time. To obtain a fair sample, it has been found sufficient to have one orifice to draw off gases through for each 25 sq. inches of flue cross section. The pipes must be of equal diameter and of equal length. ¼ in. gas pipes, all alike at the ends, and of equal lengths, answer well. Similar steel tubes will be still better.* These should be secured in a box or block of galvanized sheet iron, equal in thickness to one course of brick, in such a manner that the open ends may be evenly distributed over the area of the flue, and their other open ends inclosed in the receiver B. If the flue gases be drawn off from the receiver B by four tubes, C C, into a mixing box, D, beneath, about 3 inch cube, a good mixture can be obtained. Two such "samplers," one above the other a foot apart, in the same flue, will furnish samples of gases which show by analysis the same composition. J. C. H.

XVII. CALORIMETER EXPERIMENTS.

In all boiler experiments it is important to ascertain the quality of the steam, *i. e.*, 1st, whether the steam is "saturated" or contains the quantity of heat due to the pressure according to standard experiments; 2d, whether the quantity of heat is deficient, so that the steam is wet; and 3d, whether the heat is in excess and the steam superheated. The best method of ascertaining the quality of the steam is undoubtedly that employed by a committee which tested the boilers at the American Institute Exhibition of 1871–2, of which Professor Thurston was chairman; but this plan cannot always be adopted. When all the steam generated is not condensed, the method of making the connection for the purpose of taking out a sample is of the utmost importance. Unless great care be exercised, the results will frequently show that the steam is superheated when the boiler has no superheating surface. The cause of this is pointed out at p. 82 of the writer's general report on the exhibits referred to the Judges of Group XX., Centennial Exhibition. It is not fair to take the steam direct from the boiler, for if there be no steam circulation at that point the steam will of course show dry. The samples should be taken from the main steam pipe, but not from the bottom, as this would take all the water draining to that point. The method of taking it through a perforated pipe crossing the main steam pipe is sure to cause difficulty whenever the velocity of steam flowing to the calorimeter is sufficient to reduce the pressure in the supply pipe, for in such case the temperature of the steam in that pipe falls at the inlet, and the steam of full pressure and higher temperature flowing through the main pipe adds heat to that flowing into the calorimeter pipe, so that the latter, when referred to the pressure from which it is derived, shows superheating. The same effect takes place in a less degree when the steam for the calorimeter is taken through a lateral opening of small diameter, the metal surrounding the opening being kept warm by the current passing through the main pipe, and imparting its heat to the steam flowing in the lateral pipe to the calorimeter. To avoid this difficulty, the writer recommends making the lateral opening leading to the calorimeter 1½ to 2 inches in diameter, and then at a little distance from the main pipe, say 1 foot, reducing the supply pipe to calorimeter to ¾ or ½ inch diameter.

For general use the writer prefers the ordinary barrel calorimeter, which has the advantage over a continuous calorimeter operating at a slow rate of flow, that with the latter the condensation in the connecting pipes may cause the small quantity of steam flowing to the calorimeter to be moist, and thereby vitiate the results. With the barrel calorimeter it is desirable to heat the water promptly, so that the question of condensation in connecting pipes is of minor importance. At the same time the quantity of steam drawn off should not be so great, in connection with that passing to other points, as to cause the boiler to foam, or to reduce the pressure.

The practice of the writer is to use a barrel, holding preferably 400 lbs. of water, which is set upon a platform scale, and provided with a cock or valve for allowing the water to flow to waste. I have always provided a small propeller made with blades simply cut out of a disc of sheet iron, twisted to give the pitch and bolted on to the bottom of a vertical rod supported in a wooden step in the

* Because smoother and more uniform.

bottom of the barrel, and passing through a cross piece on the top of the barrel. The rod terminates at the top in a crank, and a collar is placed on the vertical shaft under the upper support. A fixed thermometer is run through a cork in the bunghole of the barrel. The pipe conducting the steam from the main steam pipe is made of graduated sizes, as previously referred to, and the smaller pipe provided near the calorimeter with a valve connected by means of a coupling with a rubber hose. In the coupling is to be placed a disc of metal, provided with a regulating hole of from $\frac{3}{16}$ to $\frac{1}{4}$ in. in diameter.

To operate the calorimeter the barrel is filled with water, the weight and temperature ascertained, steam blown through the hose outside the barrel until the pipe is thoroughly warmed, when the hose is suddenly thrust in the water, and the propeller operated until the temperature of the water is increased to the desired point, say about 110° usually. The hose is then withdrawn quickly, the temperature noted, and the weight again taken. The object of the particular details adopted will be readily understood. The simple propeller insures a uniform heating of the whole of the water. The little disc in the supply pipe enables the stop valve in pipe from boiler to be opened wide without drawing off so large a quantity of steam as to lower the pressure or produce priming. To avoid the jar when the steam hose is in the water, it is better to cut some lateral holes in the hose near its lower end. In this way a circulation is induced through the holes which prevents most of the jar and noise.

The weight of water in calorimeter should be increased proportionally to the weight and specific heat of all metal exposed to changes of temperature with the water. An addition of one-ninth of the weight of the propeller and submerged portion of shaft and fastenings will be substantially correct if the apparatus be made of iron.

The importance of errors of measurement or observation are inversely proportional to the magnitudes of the quantities. The weight of water added by condensation of steam being comparatively small, it must be weighed accurately, say within a quarter of one per cent. The writer has done this on an ordinary platform-scale in good order by using a second movable poise, in addition to the customary one, and of one-tenth its weight. In weighing, the lighter poise is adjusted to bring the free end of the beam to a fixed mark. The same result may be obtained by loading the platform with small known weights to bring the lever to a fixed point each time, and deducting such weights from the reading of scale in regular notches.

The above must be considered a makeshift, but a valuable one. When possible, delicate scales should be employed, and, in the opinion of the writer, better satisfaction can be obtained in this direction than by the use of the more complicated apparatus required to weigh the water of condensation separate.

In making the calculations the following notation and formula prepared by the writer for the report of the Committee having in charge the testing of the boilers of the Centennial Exhibition will be found convenient:

Let W = original weight of water in calorimeter.

Let w = weight of water added by heating with steam.

Let T = total heat in water due to the temperature of steam at observed pressure.

Let H = total heat of steam at observed pressure.

Let l = latent heat of steam at observed pressure = (H − T).

Let t = total heat of water corresponding to initial temperature of water in calorimeter.

Let t' = total heat in water corresponding to final temperature of water in calorimeter.

Let Q = quality of steam.

Then

$$(1) \qquad Q = \frac{1}{l}\left(\frac{W}{w}(t'-t)-(T-t')\right).$$

Then when $Q < 1$, percentage of moisture in steam $= 100\,(1-Q)$.

When $Q < 1$, number of degrees steam is superheated $= 2.0833\,l\,(Q-1)$.

The later practice of the writer when there are a large number of calculations to be made is as follows:

Add to above notation the following:

Let m = percentage of moisture in steam.

Let s = number of degrees steam is superheated.

Let A = number of heat units lacking per pound of steam condensed. Equals quantity in parenthesis, Equation (2).

Let Σ = sign of summation. To be read: Some of values of—

Let n = number of experiments to be averaged.

Then

.....A.....

$$(2) \qquad m = \frac{1}{l}\left((H - t') - \frac{W}{w}(t' - t)\right).$$

$$(3) \qquad Q = 1 - m.$$

When A or m is minus.

$$(4) \qquad s = -2.0833\ A.$$

Averaging several experiments.

$$(5) \qquad m = \frac{\Sigma A}{nl}$$

$$(6) \qquad s = -2.0833\frac{\Sigma A}{n}.$$

C. E. F.

XVIII. NOTE ON USE OF THE BARREL CALORIMETER.

In the use of the barrel calorimeter not less than 300 lbs. of water should be used, and it is an advantage, when practicable, to cool the water by means of pulverized ice. By vigorous agitation the water may thus be cooled to 36° F., or even 34° F., in a few minutes, when the remaining ice is to be completely removed. As the ice floats on the surface, this can be readily done. The weight of steam condensed can thus be often doubled, and still the temperature of the water not be raised above 100° F., at which point no sensible loss of heat will be suffered through evaporation. The greater the weight of steam condensed, the less will be the unavoidable percentage of error.

If the barrel be covered with a non-conductor, it will be found that no sensible change in the temperature of the water will take place in a long time.

C. T. P.

XIX. EFFECT OF SMALL ERRORS OF OBSERVATION IN CALORIMETER TEST.

Suppose a case in which errors of observation occur, as in the following table:

	Observed Reading.	True Reading.	Amount of error.
Weight of condensing water, corrected for equivalent of apparatus, W	200.5 lbs.	200 lbs.	½ pound.
Weight of condensed steam, w	9.9 "	10.0 "	$\frac{1}{10}$ "
Pressure of steam by gauge, P	78. "	80 "	2 pounds.
Original temperature of condensing water, t	44.5° "	45° "	½ degree.
Final " " " " t	100.5° "	100° "	½ "

The formula for calculation is

$$Q = \frac{1}{H - T}\left(\frac{W}{w}(h - h_1)\right) - (T - h_1)$$

in which Q = quality of the steam, dry saturated steam being unity.

H = total heat of steam at observed pressure.

in which T = total heat of water at observed pressure.

h = total heat of condensing water, original.

h_1 = total heat of condensing water, final.

		Moisture per cent.	Error per cent.
Substituting in the formula the "true readings" in the table, we have for the value of	Q = 0.9874	= 1.26	= 1.
All readings true except W = 200.5,	Q = .9906	= 0.94	= 0 32
" " " w = 9.9,	Q = 1.0000	= 0.00	= 1.26
" " " P = 78. ,	Q = .9880	= 1.20	= 0.06
" " " t = 44.5,	Q = .9986	= 0.11	= 1.15
" " " t' = 100.5,	Q = .9994	= 0.06	= 1.20
" " incorrect..	Q = 1.0272	= (minus)	= 3.98

The last case, Q=1.0272, is equivalent to 50.2 degrees superheating.

The errors above noted are all such as may easily occur even with good apparatus. The condensing water being usually weighed in a barrel on an ordinary platform scale, an error of $\frac{1}{2}$ a pound could easily be made if the scale were not carefully tested and standardized. To make as small an error as $\frac{1}{10}$ of a pound in the weight of the condensed steam, when it is weighed in the bulk with the condensing water, taking the difference of readings before and after the test, is almost more than can be expected. The probable error of such a method of weighing the condensed steam is usually more than a quarter of a pound. The error in this weight is the most important of all those given in the table, showing dry steam, Q=1.00, instead of 1.26 per cent. moisture, the true result. If the error of the weight of the condensed steam were $\frac{1}{4}$ lb., it would be equivalent to an error of 3 per cent. in the calculated moisture in the steam, and consequently of 3 per cent. in the total result of the boiler test. The error of steam pressure, 2 lbs., is well within the limit of error of many steam gauges, but as seen in the result, it is the least important of all the errors, giving 1.20 per cent. moisture instead of 1.26 per cent. The errors of $\frac{1}{2}$ a degree in temperature of condensing water are also quite important, and show the necessity of having thermometers carefully standardized. The effect of an error of weighing the condensed steam is so serious, and it is so likely to occur, that in the writer's opinion the method of making tests with a barrel on a platform scale, without any special weighing of the condensed steam, is so inaccurate that it should be discouraged, or at least that the results obtained by it should be considered as having a probable error of 3 per cent. It is questionable whether averaging a large number of results so obtained will give any greater approach to truth, for the errors of weighing in a barrel on a coarse platform scale, of the condensed steam together with the condensing water, due to personal equation, to absorption and evaporation of water, to error of sliding or stationary poise, and to friction of scale are apt to be, comparatively, constant, and may by no means be expected to balance each other.

W. K.

XX. COIL CALORIMETER.

The following is a description of a calorimeter, which the writer has found to give fairly good results, but sufficient experiments have not yet been made with it to determine its limit of error:

A surface condenser is made of light weight copper tubing $\frac{3}{4}''$ in diameter and about 50′ in length, coiled into two coils, one inside of the other, the outer coil 14″ and the inner 10″ in diameter, both coils being 15″ high. The lower ends of the coils are connected by means of a brazed T-coupling to a shorter coil, about 5′ long, of 2″ copper tubing, which is placed at the bottom of the smaller coil and acts as a receiver to contain the condensed water. The larger coil is brazed to a $\frac{3}{4}''$ pipe, which passes upward alongside of the outer coil to just above the level of the top of the coil and ends in a globe valve, and a short elbow pipe which points outward from the coil. The upper ends of the two $\frac{3}{4}''$ coils are brazed together into a T, and connected thereby to a $\frac{3}{4}''$ vertical pipe provided with a globe valve, immediately above which is placed a three-way cock, and above that a brass union ground steam tight. The upper portion of the union is connected to the steam hose, which latter is thoroughly felted down to the union. The three-way cock has a piece of pipe a few inches long, attached to its middle outlet and pointing outward from the coil.

A water barrel, large enough to receive the coil and with some space to spare, is lined with a cylindrical vessel of galvanized iron. The space between the iron and the wood of the barrel is filled with hair felt. The iron lining is made to return over the edge of the barrel, and is nailed down to the outer edge so as to keep the felt always dry. The barrel is furnished also with a small propeller, the shaft of which runs inside of the inner coil when the latter is placed in the barrel. The barrel is hung on trunnions by a bail by which it may be raised for weighing on a steelyard supported on a tripod and lifting lever. The steelyard for weighing the barrel is graduated to

tenths of a pound, and a smaller steelyard is used for weighing the coil, which is graduated to hundredths of a pound.

In operation, the coil, thoroughly dry inside and out, is carefully weighed on the small steelyard. It is then placed in the barrel, which is filled with cold water up to the level of the top of the globe valves of the coil and just below the level of the three-way cock, the propeller being inserted and its handle connected. The barrel and its contents are carefully weighed on the large steelyard; the steam hose is connected by means of its union to the coil, and the three-way cock turned so as to let the steam flow through it into the outer air, by which means the hose is thoroughly heated; but no steam is allowed to go into the coil. the water in the barrel is now rapidly stirred in reverse directions by the propeller and its temperature taken. The three-way cock is then quickly turned, so as to stop the steam escaping into the air and to turn it into the coil; the thermometer is held in the barrel, and The water stirred until the thermometer indicates from five to ten degrees less than the maximum temperature desired. The globe valve leading to the coil is then rapidly and tightly closed, the three-way cock turned to let the steam in the hose escape into the air, and the steam entering the hose shut off. During this time the water is being stirred, and the observer carefully notes the thermometer until the maximum temperature is reached, which is recorded as the final temperature of the condensing water. The union is then disconnected and the barrel and coil weighed together on the large steelyard; the coil is then withdrawn from the barrel and hung up to dry thoroughly on the outside. When dry it is weighed on the small scales. If the temperature of the water in the barrel is raised to 110° or 120° the coil will dry to constant weight in a few minutes. After the weight is taken, both globe valves to the coil are opened, the steam hose connected, and all of the condensed water blown out of the coil and steam allowed to blow through the coil freely for a few seconds at full pressure. When the coil cools it may be weighed again, and is then ready for another test.

If both steelyards were perfectly accurate, and there were no losses by leakage or evaporation, the difference between the original and final weights of the barrel and contents should be exactly the same as the difference between the original and final weights of the coil. In practice this is rarely found to be the case, since there is a slight possible error in each weighing, which is larger in the weighing on the large steelyard. In making calculations the weights of the coil on the small steelyard should be used, the weights on the large steelyard being used merely as a check against large errors.

It is evident that this calorimeter may be used continuously, if desired, instead of intermittently. In this case a continuous flow of condensing water into and out of the barrel must be established, and the temperature of inflow and outflow and of the condensed steam read at short intervals of time. W. K.

XXII. REPORTING THE RESULT.

As to reporting the results of boiler tests—two things are necessary, in order to make the reports (*a*) generally intelligible, and (*b*) strictly comparable.

1. The number of pounds of water actually evaporated under stated (actual) conditions of feed-water temperature and steam-gauge pressure, into steam containing not over three per cent. of entrained water, by each pound of coal burned—coal of good mercantile quality, dry; water dried out of a sample and allowed for, or, containing not over one-half per cent. of surface moisture, by actual experiment of drying samples. In this latter case, the one-half per cent. of water in the coal, like the three per cent. of entrained water in the steam, and the stated quantity of ashes and refuse in the coal, are taken in for the sake of representing usual conditions. So much for *general intelligibility*.

2. The equivalent evaporation in pounds of water of t=212° F. converted into dry saturated steam of one atmosphere pressure, = 760 mm = 29.92 in. mercury—with one pound of *dry* combustible consumed. This for *strict comparability*.

It is obvious, if attention be given to the subject—too often neglected—that all the surface water in the coal, if not ascertained and allowed for, will appear

as combustible and disappear as water evaporated.

For example, two per cent. of water in the coal, passing over the bridge wall and going up chimney, leaving no weight to represent it in the "ashes and residue," will increase the item of "combustible" by two per cent. of the gross weight of the coal; and if ashes and residue $=\frac{1}{6}$ of the gross weight, the addition will be 2 per cent $\times \frac{6}{5} = 2.4$ per cent. At the same time about two-ninths of one per cent. of the water evaporated will escape observation, going up chimney unnoticed.

There should also be introduced into general practice an equivalent statement, of

3. The equivalent evaporation in pounds of water from feed-water temperature $= 100°$ F. into usual steam containing not over three per cent. entrained water of seventy pounds per square inch pressure by steam gauge, above 1 atmosphere $= 760$ mm. $= 29.92$ inches mercury—for each pound of commercial coal containing not over one-sixth ashes and residue including surface water; one pound of such commercial coal being capable of imparting to the water in a boiler of good proportions about 10,000 British thermal units.

XXIII. REPORTING THE TEST.

The report should include a complete description of the boiler, which, for special boilers, should be written out at length, but generally can conveniently be presented in tabular form, substantially as follows:

Type of boiler.
Diameter of shell.
Length of shell.
Number of tubes.
Diameter " "
Length " "
Diameter of steam drum.
Width of furnace.
Length of furnace.
Kind of grate bars.
Width of air spaces.
Ratio of area of grate to area of air spaces.
Area of chimney.
Height of chimney.
Length of flues connecting to chimney.
Area of flues connecting to chimney.

GOVERNING PROPORTIONS.

Grate surface.
Heating surface { Water. Steam. Total.
Area of draft through or between tubes.
Ratio grate to heating surface.
" draft area to grate.
" " " total heating surface.
Water space.
Steam space.
Ratio grate to water space.
" " " steam space.

C. E. E.

XXIV. OBSERVATION BLANKS.

The observations taken during a test should be recorded on a series of blanks prepared in advance so as to be adapted to the purposes of the trial. The number of sheets and the particular items on each may be varied to suit the number of observers and the work designated for each. The following are copies of observation blanks used in the Centennial trials with a few lines of figures inserted, without reference to each other, for the purposes of illustration. The columns should, of course, be of sufficient length to contain the number of observations expected. C. E. E.

XXV. HORSE-POWER.

The writer's preference for rating boilers in horse-power is:

Capacity to evaporate into dry steam, *i. e.*, not containing over three per cent. of entrained water, and the water actually entrained allowed for and deducted:

1. $34\frac{1}{2}$ pounds of water from and at 212°, equal to

2. 30 pounds of water of $t=100°$ under $p=70$ pounds per square inch above one atmosphere; with easy firing, moderate draught, and ordinary fuel, implying good economy, and capability of fifty per cent. increase to meet emergencies.

As to the last condition, "capability of fifty per cent. increase to meet emergencies," it must be obvious that a boiler which, under most favorable conditions of fuel, draught, firing, and everything else, just capable of evaporating into dry steam 3,450 pounds of water from 212° into

Log of Trial of Boiler.

NO. 1.—RECORD OF FEED WATER.

1	2	3	4	5	6	7	8
Time.	Tank A.			Tank B.			Height of Water in Glass.
	Initial Weight.	Final Weight.	Temperature.	Initial Weight.	Final Weight.	Temperature.	
Hrs. Min. A. M.	Lbs.	Lbs.	Deg. Fah.	Lbs.	Lbs.	Deg. Fah.	Ins.
5.22	——	——	—	——	——	——	7
6.19	1442.5	136	63	——	——	——	0
6.40	——	——	—	1421.5	169.5	63.5	6
7.05	1447	131.5	68	——	——	——	6
7.28	——	——	—	1431.5	193.5	67	7
8.00	1445.5	316	67	——	——	——	5

Deduct 56.25 pounds of feed-water for difference of level in boiler.

Log of Trial of Boiler.

NO. 2.—GENERAL OBSERVATIONS—COAL AND ASHES.

9	10	11	12	13	14	15	16	17	18	19	20	21
Time.	Steam Pressure.	Temperatures. (Fahrenheit.)					Coal and Ashes.				Barometer.	Height of Water in Glass.
		Air.	Fire-Room.	Steam.	Uptake.		Coal Weighed out on Floor.	Coal Consumed.	Coal found in Ashes.	Weight of Ashes. *Net.*		
					Ther.	Pyr.						
Hrs. Min. A. M.	Lbs.	Deg.	Deg.	Deg.	Deg.	Deg.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.
9.22	70	49	88	310	—	375	230.5	170	578	304.5	30.20	10
10.00	70	51	82	299	—	401	229.5	Wood.	—	—	—	7
10.30	70	57	83	308	—	446	229.5	235.5	—	—	—	3
11.00	70	—	80	309	—	446	229.5	229	—	—	—	0.5
11.30	70	55	80	299	—	432	223.5	221.5	—	—	—	10
12.00	70	—	80	298	—	444	231	227	—	—	—	8

LOG OF TRIAL OF BOILER.

NO. 3.—RECORD OF CALORIMETER EXPERIMENTS.

22	23	24	25	26	27	28
Time.	WATER.			TEMPERATURES. (Fahrenheit.)		Steam Pressure.
	Weight of Barrel.	Initial Gross Weight.	Final Gross Weight.	Initial.	Final.	
Hrs. Min. A. M.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Lbs.
5.35	80.5	400	412.5	73.5	106.125	70 —66
5.55	80.5	400	413.375	68.25	110.50	70 —67
6.15	80.5	400	411.375	72.50	111	70 —68.5
6.35	80.5	400	417.25	66	122	70 —68
6.55	80.5	400	415.125	67.5	114.25	70 —64
7.15	80.5	400	416	74.5	122.25	70 —66
7.35	80.5	400	411.75	74.5	113.75	69 —70
7.55	80.5	400	413.25	72.5	115.25	70 —65
8.15	80.5	400	413.25	71	112.75	70 —62

the atmosphere, with open safety valve—or, what comes to the same thing, 3,000 pounds from $t = 100°$ to $p = 70 +$ atm. could not be called a 100 horse-power boiler with any propriety. Good ordinary practical conditions should do that, with satisfactory economy; and then fifty per cent. more should be obtainable to meet a sudden call, or to supply a brief deficiency. J. C. H.

XXVI. STEAM UNITS.

All measurements of the quantity of heat are based on the *thermal unit*, which, for British measures, equals the quantity of heat required to raise the temperature of one pound of pure water at or near its freezing point one degree Fahr.*

The unit commonly used to express the evaporative power of the fuel is the quantity of heat required to evaporate one pound of water at a temperature of 212° under the ordinary pressure of the atmosphere corresponding to that temperature. This was called by Rankine a "peculiar thermal unit," and its value given at 966.1 British thermal units, but has since been called the "*unit of evaporation*," which term is adopted in the foregoing general report of the committee. Its value, however, in the prominent American tables is given at 965.7 thermal units.

The *mechanical equivalent* of a thermal unit equals very nearly 772 foot-pounds of work, but the power that can be utilized practically per unit of heat depends on so many conditions that a universal standard of work or power (the rate of work) based on heat units, is impossible. Compound engines operated with high steam slightly superheated, require a little over 14 pounds of feed-water evaporated per hour, while there are still in use poor engines, ill-proportioned steam pumps, and the like, that require over 60 pounds, or say one cubic foot of water per hour, which was considered as about equivalent to a horse-power of steam in the days of

* Compare Rankine on Steam Engine, Art 298; Porter on the Richards Indicator, page 43.

Watt. It has of late years, however, been well accepted that 30 pounds of feed-water per hour is a fair standard of horse-power for average good high-pressure engines, such as are used for manufacturing purposes. Bearing in mind that this quantity of steam must be furnished by the boiler under actual conditions, the writer, in preparing the report of the committee of the judges of Group XX. appointed to test the boilers at the Centennial Exhibition, suggested to his associates, Messrs. Chas. T. Porter and Joseph Belknap, that the value of the "Commercial horse-power of a boiler be fixed at 30 pounds of water evaporated at 70 pounds gauge-pressure from a temperature of 100°."* This standard having been adopted in the foregoing report of the committee of the American Society of Mechanical Engineers, may be considered as established both by precedent and authority. It is fixed as equal to 34½ units of evaporation per hour, and is, for all practical purposes, equal to 33,333 thermal units per hour, making it convenient to obtain the horse-power by multiplying the total number of thermal units derived from the fuel per hour by 0.00003. It is of interest also to note that a cubic foot of steam at 70 pounds gauge pressure weighs 1-5 of a pound avoirdupois, so that a Commercial Horse-power on the above basis is also represented by 150 cubic feet of steam per hour at 70 pounds pressure.

In administering the steam supply of the New York Steam Company, the writer provided for selling steam at a fixed rate per thousand "*kals.*," explaining that a "*kal.*" meant a pound of water evaporated into steam. This term has been in use in that business since February, 1883, and has proved so convenient that the writer has suggested that it can possibly be utilized to express the unit of the Commercial Horse-power above referred to. On this basis a boiler horse-power would equal simply 30 "Kals" per hour.†

In preparing the general report of the judges of Group XX., Centennial Exposition, it was observed that if a boiler supplying any kind of pumping machinery be proportioned to utilize 10,000 heat units per pound of coal consumed (corresponding to an evaporation of about 9 pounds of water at 70 pounds gauge-pressure from a temperature of 100°) the number of foot-pounds of work obtained in the engine for each thermal unit would also represent the duty, in millions of foot-pounds of work obtained in the engine, for each thermal unit would also represent the duty, in millions of foot-pounds per 100 pounds of coal.*

From this it will be seen that the Commercial Horse-power above referred to corresponds to a duty of 59.4 millions of pounds lifted one foot high with 100 pounds of coal, which is about the average duty of the simpler class of pumping engines, but not of first-class engines. Evidently, for the better class of steam machinery of all kinds, the steam producing capacity of the boiler must be made to conform to the actual amount of steam to be used by the engines. Any standard of the horse-power of a boiler necessarily relates simply to its steam-producing capacity, referred to the arbitrary standard of a horse-power above mentioned. C. E. E.

* See Report of Committee at page 131 of the report of the Judges of Group XX. International Exh., 1876. J. B. Lippincott & Co., Philadelphia.

† See "Estimates for Steam Users," Vol. V. Transactions American Society Mechanical Engineers, page 284.

XXVII. MEMORANDUM RELATIVE TO A STANDARD METHOD OF TRIAL-TEST FOR STEAM BOILERS.

The method customarily pursued in the course of the work of the Mechanical Laboratory of the Stevens Institute of Technology, as instituted by the writer, and that practiced in his own professional work, has usually been such as to secure data sufficient to enable the observer to fill out all the columns of the Log-blank and Table of Performance, copies of which are appended.

In starting the trial, which is usually of at least ten hours' duration, it is customary, where it can be conveniently done, to get up steam with a fire of wood, which is raked out after steam has begun to form freely, and the trial commences with the introduction of a new fire, in which wood is used to ignite the coal, and is charged as a certain percentage of its weight of coal—forty per cent. is probably as accurate as need be. The damper should be carefully closed during the few

* See Report of Judges of Group XX., Cent. Exh., pp. 21 and 115.

minutes required to perform this operation. Toward the end of the time fixed for the trial, the steam pressure and height of water are made as nearly identical with the same conditions at the beginning as is possible, the fire is burned as low as the skill of the fireman and supervising engineer will permit, and when the end of the trial is recorded, the fire is hauled, the coal and ashes weighed dry, no more water being used in cooling them as they are drawn than is absolutely necessary for the comfort of the fireman, and never sufficient to leave any portion of the mass in the slightest degree damp.

Where it is impracticable to start with a new fire, and to remove the fire at the end of the trial, it is preferred to begin and end the trial with the cleaning hour, the quantity of coal being then most easily estimated and identical conditions being thus most readily approximated.

The steam pressure is read from a gauge which it is intended shall always be carefully standardized both before and after the trial. The same precaution should be taken with all instruments used whenever possible.

During the trial, all the conditions are kept as nearly uniform as is possible, and as exactly those for which the boiler is designed as is practicable. The supply of feed-water and of fuel, the pressure of steam, the frequency of firing or "stoking" are to be made definitely constant. A continuous feed rather than an intermittent supply of water is much preferred, and the injector is preferred where choice of instrument is permitted. The customary mode of feeding is, however, often best, whatever that may be. Determinations of the character of the steam made are considered essential in every case. The open, or "barrel," calorimeter of Hirn has been generally employed, making the number of observations sufficient to give a small margin of probable error. It is hoped that the relative value of the different forms may after a time be so well determined as to permit the acceptance of some one as a standard. The intermittent instrument consisting of a coil of pipe in a vessel of water and the continuous calorimeter, such as was proposed by Van Buren some years ago, and used by Skeel and the writer, and modifications since made by many others, are capable of doing good work; but engineers greatly differ in their estimates of their relative value, and the simplest form is at present in most general use, probably because of its portability, or the ease with which it can be improvised. Could it be done, the method of condensing all the steam made, as practiced at the American Institute trials of 1871, would be always adopted, in preference to the system of "sampling."

In the analysis of gases, the apparatus made by Greiner and Linke is found convenient when it is considered necessary to make such analyses. In fuel analysis, Monroe's system of carbon determination by the use of lead oxide is probably as easy and as satisfactory as any for general use. More complete analyses are entrusted to a professional chemist, and are made in the chemical laboratory. The draft-gauge used is that designed by Mr. Allen for the Hartford Steam Boiler Insurance Co.

General Principles. In the operation of conducting a trial of a steam-boiler, we have, usually, a single, well-understood object in view, and the engineer should accustom himself to carefully define that object in his own mind, and to as carefully describe that object in his instructions and regulations for the proposed trial. The whole operation can then be carried on with that point distinctly in view, and the proposed end can then be accomplished with maximum economy of time and labor, as well as with greatest exactness. The observations must be made by the engineer conducting the trial, or by his assistants, with this object distinctly in mind, and each should have a well-defined part of the work assigned him, and should assume responsibility for that part, having a distinct understanding in regard to the extent of his responsibility, and a good idea of the extent and nature of the work done by his colleagues, and the relations of each part to his own. No observations should be permitted to be made by unauthorized persons for entrance upon the log; and no duties should be permitted to be delegated by one assistant to another, without consultation and distinct understanding with the engineer in charge. The aim of the observers is, in all cases, to obtain an exact determination of the weight of fuel used,

its proportion of combustible matter effective in developing heat, the exact weight of water evaporated under the known conditions of the trial, into steam, the determination of the character of that steam, and often the nature of the combustion, and the composition of the furnace-gases. Each of these distinct objects requires the determination of certain well-defined quantities, and the observer to whom each set of observations is entrusted should, whenever possible, be made sufficiently well acquainted with the object to be attained, and the method to be pursued in reaching it, to be able to make his own readings with accuracy, and to work up the results correctly. It is only after he has acquired this knowledge that he can be expected to do his work without direct supervision, and with satisfactory precision. The trial should, wherever possible, be so conducted that any error that may occur in the record may be detected, checked, or, if advisable, removed, by some process of mutual verification of related observations. It is in this direction that the use of graphical methods of record and automatic instruments have greatest value. We should lose no opportunity to introduce both.

Weighing Fuel.—Several methods of weighing fuel have been found very satisfactory, in the writer's experience; but he is inclined to make it an essential feature of either that the weights shall be made by one observer, and checked by another, at as distant a point as is convenient. The weighing of the fuel by one observer, at the point of storage, and the record at that point of times of delivery, as well as of weights of each lot, and the tallying of the number and record of the time of receipt, at the furnace-door, will be usually found a safe system. The introduction of unweighed coal, whether by accident, or by design on the part of some interested person, can never be too carefully guarded against. The failure to record any one weight, which is not an unknown accident, leads to similar error, and can only be certainly prevented by an effective method of double observation and check.

Weighing Feed-Water.—The same remarks apply, to a considerable extent, to the weighing of the water fed to the boiler. A careful arrangement of weighing apparatus, a double set of observations, where possible, and thus safe checks on the figures obtained, are essential to certainty of results. With good men at the tank, and with small demand for water, a single tank can be used; but two are preferable, in all cases, and three should be used if the work demands very large amounts of feed-water, as at trials of very large, or of "batteries" of boilers. The more uniform the water supply, as well as the more steady the firing, the less the liability to mistake in making the record.

Character of Steam.—It has been the endeavor of every engineer conducting trials of boilers, of late, to secure correct determinations of the quantity of water entrained with the steam, or of the degree of superheating, where superheating occurs. This is, however, a matter of considerable difficulty. It was, so far as the writer is aware, first proposed and attempted by Hirn, the distinguished French engineer and physicist, who, many years ago, used what is now known as the tank, or barrel, calorimeter for this purpose. A jet of steam from the boiler was led into a tank containing a considerable mass of water, and condensation was allowed to go on until the water had acquired as high a temperature as was convenient. The amount of "priming" was then calculated by a comparison of the amount of heat transferred to the barrel, by the weight of steam taken from the boiler, with the amount that would be transferred by the same weight of perfectly dry steam.

This method was in use some years when the continuous calorimeter was proposed by Van Buren. This form was adopted by a committee, of which the writer was chairman, in the year 1875, in making tests of "sectional" boilers, the instrument used being designed by the late Mr. Theron Skeel, a member of the committee. The results of its work were satisfactory to the committee.

The method of testing the character of steam made in boilers by this system of sampling seemed somewhat open to doubt in respect to its accuracy, when used by Hirn, and, for a long time, the writer looked for an opportunity to determine with certainty what is the real amount of priming, under ordinary conditions of operation, in the common forms of boiler. This was finally offered in the year 1871, when as chairman of a committee on boiler trials for the American Institute,

Table II.

Average and Total Results of Trial of Mechanical Laboratory, Department of Engineering, Stevens Institute of Technology.

TRIAL MADE *FUEL.*

*at*_____

*on*_____ *COMPOSITION.*

Number of Trial.	Date of Trial.	Length of Trial.	Areas.				Ratio of Grate to Heating Surface.	Average Temperatures.				Average Pressures.			Consumption of Fuel.			Ashes.			Remarks.
			Grate.	Heating Surface.	Super-Heating Surface.	Least Cross-Section of Flues.		Boiler Room.	External Air.	Entrance to Chimney.	Feed-Water.	Barometer.	Steam Gauge.	Draught Gauge.	Total.	Per square foot of Grate per hour.	Per sq. ft. of Heating Surface per hour.	Total.	Proportion of Total Fuel.	Total Combustible.	
		Hours.	sq. ft.	sq. ft.	sq. ft.	sq. ft.		Fahr.	Fahr.	Fahr.	Fahr.	ins.	lbs.	ins.	lbs.	lbs.	lbs.	lbs.	per ct.	lbs.	

Apparent Evaporation.									Real Evaporation.											
Per Pound of Fuel.			Per Pound of Combustible.			Per square foot of Heating Surface, per Hour.			Per Pound of Fuel.			Per Pound of Combustible.			Per Square foot of Heating Surface, per Hour.			Sq. ft. of Heating Surface required to Evaporate one Cu. ft of Water.		
From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*	From actual temp. of Feed-Water and at actual S. P.*	Equivalent fro. & at 212° F.	Equivalent fro. 212° F. & at actual S. P.*
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	sq. ft.	sq. ft.	sq. ft.

* Steam Pressure.

TABLE II.—*Continued.*

TOTAL WATER FED TO BOILER.			Average Priming.	Total Water Primed.	WATER EVAPORATED INTO DRY STEAM.			REMARKS.
From actual temperature of Feed-Water and at actual steam pressure.	Equivalent from and at 212° F.	Equivalent from 212° F. and at actual steam pressure.			From actual temperature of Feed-Water and at actual steam pressure.	Equivalent from and at 212° F.	Equivalent from 212° F. and at actual steam pressure.	
lbs.	lbs.	lbs.	per cent.	lbs.	lbs.	lbs.	lbs.	

Average Amount of Superheating.	EVAPORATION FROM AND AT 212° F., EQUIVALENT TO TOTAL HEAT UNITS DERIVED FROM FUEL.			EFFICIENCY.			Values of A and B in $F = A\sqrt{H} \pm B$		HORSE-POWER.		REMARKS.
	Per pound of Fuel.	Per pound of Combustible.	Per sq. foot of Heating Surface, per hour.	Experimental.	Estimated.	$R = \frac{\text{Experimental.}}{\text{Estimated.}}$	A	B	Rated.	Actual.	
Fahr.	lbs.	lbs.	lbs.	per cent.	per cent.						

it became necessary to arrange for a comparison of several competing boilers of, fortunately, widely different types and forms. Through the liberality of Mr. J. B. Root, and with the earnest co-operation of Mr. Chas. T. Porter and others of the then exhibitors, it was rendered possible to construct a large surface-condenser, in which to condense *all* the steam made by each boiler during its trial. The arrangements were made with great care, and conducted under the writer's own personal direction and supervision, by carefully selected observers, and with the most cheerful and gratifying co-operation on the part of all the competing exhibitors. The result was the determination, with the most satisfactory certainty, of the real amount of total priming, as ascertained by observation of the total amount of water passing of as steam, and of the total amount of water carried out of the boiler unevaporated. Two of the boilers superheated their steam slightly; the others primed from three to seven per cent. The main object of the investigation, the determination of the question whether sampling steam can give fairly correct measures of the character of the mass, was in the writer's opinion well settled affirmatively by these experiments.

As to the best form of calorimeter, the writer is not yet fully satisfied, and hopes to find a way of making one that shall be at once simple, easily transported, and accurate. He has a strong impression that it will be a continuous calorimeter, but has very little doubt that improvements in accessory apparatus now in progress may make the Hirn form of instrument, sooner or later, a satisfactory one. The best work thus far has been done probably by the intermittent form of coil condenser, although experience with the continuous instrument has been very encouraging. Mr. Hoadley has done some beautiful work, and the apparatus described by Mr. Kent gives a means of checking weights, which is a very useful and almost essential improvement upon that type of instrument.

A steam-boiler trial in which the quality of the steam is not, as least approximately determined, cannot be accepted to-day as giving any reliable measure of the efficiency of a boiler.

Near the end of the series of data recorded in the blanks appended, are columns intended to include the constants, as derived from the trial, for introduction into the formulas of Rankine for efficiency of boiler, and of the writer for that of chimney. It was the writer's expectation to be able, in course of time, to accumulate such an extensive set of data in this form as would enable Rankine's formula to be adjusted for use in all trials of the usual forms of boiler, and with our native fuels. The American fuels, and our common boilers, cannot be estimated, in respect to efficiency, by the use of that formula, with the degree of exactness that is desirable. The writer has been accustomed, in making such estimates, as a rule, to adopt a value of the constant multiplier less by about ten per cent. than that given by the author of the formula. It is hoped that an opportunity, ere long, will be afforded to make the comparison here alluded to. R. H. T.

ON REPAIRING THE CABLES OF THE ALLEGHENY SUSPENSION BRIDGE AT PITTSBURGH, PA.

By FRANCIS COLLINGWOOD, M. Inst. C.E., M. Am. Soc. C.E.*

Selected Papers of the Institution of Civil Engineers.

The author was called upon, in August, 1883, to examine the suspension bridge across the Allegheny River at Pittsburgh, and to report upon its condition. The bridge had been in constant use since 1861, having been built by the late Mr. John A. Roebling, well known as a designer of this type of bridge. It consists of two full spans of 343 ft. 2 in. length each, and two half spans of 179 ft. 1 in. each. The floor is about 41 ft. wide, and is supported on four cables made of iron wire of an average diameter of 0.145 in. The inner cables are 22 ft. between their centers at the lowest point. spreading to 26 ft. at the points of suspension. Each cable contains two thou-

* In recognition of the merits of this paper the Telford Prize and Medal were awarded to Mr. Collingwood by the Institution of Civil Engineers.

sand one hundred wires, laid up in seven strands, and measures 7½ in. in diameter. The outer cables are 42 ft. between their centers at the lowest points, reduced to 38 ft. at the point of suspension. Each cable contains seven hundred wires, laid up in two strands, and is 4½ in. in diameter. There are heavy iron parapets at the outer sides of the sidewalks, and a system of long stays to each cable, to stiffen the bridge against vertical oscillations. The serving or so-called wrapping wire on the cables measures 0.098 in. in diameter, and is included, of course, twice in the diameter given for the cables.

The strands pass at the anchorages around cast-iron shoes, and the shoes are attached by pins to wrought-iron anchor bars. At each end of the small cables there are three, and at each end of the large cables nine, such bars. Those for the large cables are in two sets, so arranged that a rectangle surrounding the strands at the point of attachment is 22 in. square. These bars are the upper set of a series of similar ones, the lowest of which take hold of the anchor plate, and all the bars and the strands (to the clamp to be mentioned) were buried in the masonry of the anchorage.

From the shoes the strands converge for about 12 ft., at which point they are brought to a round form and held in close contact by a heavy iron clamp. From thence they are wrapped throughout, except where they pass over the saddles at the towers. Between the shoes and the clamp the wires in each strand are brought compactly together by a seizing of several turns of annealed wire at intervals of about every 7 inches. As originally finished, this unwrapped part of the cable was enclosed in heavy cotton duck, and all interior spaces were filled in solid with hot coal-tar, which had been boiled and treated with quicklime to neutralize any acid it might contain.

As an additional precaution, that portion from the clamp 3 ft. back into the masonry was surrounded by ¼-in. boiler-plate tightly clamped on, and coal-tar pitch was poured around the outer end. The whole cable for 12 ft. back, including the shoes, was then enclosed in brickwork and cement; 6-in. flags were laid in cement over the brickwork, and finally a second set of flags above these, to form the sidewalk. Over the side cables the foundations of the tool-houses took the place of the sidewalks.

Examinations had been repeatedly made at the points where the cables emerged from the masonry to see that the coverings were intact, but no more extended examination had been deemed necessary. The author felt, however, that the responsibility was too grave to allow him to assume that all was sound simply because the exterior appeared so. The sidewalk and flagging were therefore removed from over one end of a large cable, and on cutting through the canvas it was found that the tar had partially disappeared, and that the cavity was nearly full of a dirty, grayish liquid. There was also extensive rusting of the wires, so that the seizing wires, 0.06 in. in diameter, were in many cases rusted through, and the cable wires deeply pitted. A second cable end was opened, with similar results. A general survey of the bridge was then made, revealing fine cracks in the paint on the cables, which admitted moisture, grave defects in the masonry, particularly of one of the piers, and a number of other minor flaws.

A full statement of the facts was thereupon made to the directors, with the recommendation that every cable should be examined throughout and repairs made immediately; also that the cables and other ironwork should be scraped and repainted, all defective stones in the piers replaced by sound ones, the masonry repointed, and that the wrought-iron protecting-plates to the pier nosings should be repaired, &c.

Authority was given to the author to proceed with the work at once. As parts of it were entirely novel, it required close personal attention throughout. The first step was to determine how far the damage to the cables extended. One of the openings already made was therefore enlarged, and the boiler plate and wrapping removed, so as to expose the strands back to and around the shoes. It was found that the rust extended outside of the anchorage, and under the wrapping. It was then decided to remove every seizing, to cut out a slit about 45 ft. in the bridge floor to where the cable emerged above it, and to remove the clamp and

also the wrapping so far as might be necessary to discover the full extent of the damage. Accordingly about 10-ft. length of cable was unwrapped, leaving the wires exposed and entirely free for about 22 feet of their length.

On examination the serious damage to the wires was found to extend about 3 ft. from the anchorage outward. Beyond this there was a little dry rust, but no pitting; and still farther from the anchorage the paint on the interior wires was yet gummy.

The rust seemed to be of two kinds. First, a red oxide, where the wire appeared to have been attacked as if by acid, the so-called fiber being exposed. In some such cases the rust had eaten through the exterior in a narrow slit, and had then attacked the interior, leaving a shell only. The second form of rusting was by the formation of a hard blackish substance containing much sulphur, which, when scaled off, left a deep pit, as if gouged out by a chisel.

In one cable end eight wires had been eaten entirely through, and one wire or more in each of the others. Referring to the composition of the rust and the liquid found among the strands, the following letter to the author is pertinent. The writer, Professor Otto Wuth, is a practical chemist residing in Pittsburgh, and has been engaged in the manufacture of the various products resulting from the distillation of coal-tar.

PITTSBURGH, *Aug.* 18*th*, 1883.

"I have carefully examined the specimens of scales you took from the wires of the cables of the suspension bridge, and found them to be a combination of the hydrated peroxide of iron and sulphate of iron. The liquid consisted of a weak solution of carbonate and sulphate of ammonia, colored by tarry matter, and is almost identical with tar-water from the gasworks. The cables, as you stated, were first coated with boiled linseed oil, and afterwards with coal-tar. The tar had evidently not been heated long enough and high enough to drive off all the water and the salts of ammonia contained in all coal-tar at the rate of 5 to 7 per cent.

"The reaction of coal-tar is always alkaline—*very* alkaline—never acid. The reaction of the acids contained, such as carbolic and cresylic, is alkaline; they do not act like the mineral acids on iron. By heating coal-tar with caustic lime you only convert the carbonate of ammonia into caustic ammonia. Now, the action of the coal-tar upon the wires has undoubtedly been this:

"The oils contained in the tar first dissolved the coat of linseed oil; then the sulphuret of ammonia, which is contained in the tar in considerable quantity, acted upon the surface of the iron, converting it into the sulphuret of iron, which again was converted into the sulphate by the oxygen of the air, which could not have been completely excluded. This alternate action of the sulphuret of ammonia and air was continued until the sulphuret was entirely exhausted. The oxidation was further carried on by the atmospheric air in the presence of water and carbonate of ammonia."

How the water came to be where found it is not easy to say. The upper surface of the strands was but 18 in. below the surface of the sidewalk, and exposed to considerable alternations of heat and cold. A cavity was evidently formed by the tar gradually oozing into the surrounding brickwork when exposed to the heat of hot summer days. Air would then slowly percolate to and fro as the masonry changed in temperature, and moisture would probably be condensed, and the water slowly collected. It is possible that part of the sulphur and ammonia accumulated in this way, as they must be constantly present more or less in the atmosphere of such a smoky city as Pittsburgh.

It was evident that the only course to pursue was to cleanse the wires thoroughly. This was at first attempted by the use of solvents, such as benzole, kerosene, &c., but it was impossible to cleanse the interior strands in this way, even by drenching them. Scraping each individual wire was then reluctantly resorted to. After trying various scrapers, none of which worked satisfactorily, one was adopted which proved cheap and effective. A $\frac{3}{8}$-in. steel rod had one end flattened and turned up for about $\frac{1}{2}$ in., so as to make with the rod an angle of about 80°. A semi-circular notch, of about the same diameter as the wire, was then filed in the end, and the edge made sharp, hardened and tempered. With

these, four men could clean about one hundred and seventy-five wires in ten hours. To get at the interior strands, wedges were used to force them apart. Whenever a damaged wire was found, it was marked by a bit of wire twisted on. All such wires were examined, and if the loss of strength was 10 per cent., or more, it was repaired, otherwise it was passed. It was soon found that the damage was almost entirely confined to the outer two layers of wires in each strand. The seizings around the strands had held the wires so close in contact that the destructive agent had not penetrated farther.

While this preliminary work was going on, experiments were made to determine the best method of repairing the damaged wires. The only previous work of this kind, so far as known, was that done at Niagara Falls, where, in making the final splice, the two parts of a wire were kept under strain by a bar having a lever pivoted across each end. The shorter arms of these levers were provided with clamps and thumb-screws for taking hold of the ends of the wire to be joined, and gave a lever arm of 2 in. The other arms were 10 inches long. The short lever-ends having been clamped to the extremities of the cable wire, one of the long arms was fastened by a wire to some fixed object; to the second long arm a spring balance was attached, and to this a pair of small pulleys and tackle, leading finally to some other fixed object. By this means a definite pull on the balance could be transmitted to the two branches of the cable wire, since the separation of the long arms would draw the short ones towards each other.

The difficulties with this apparatus were, first, that it was not self-contained; secondly, the range of motion being small, it required exact fixing on the wires to ensure the ends being in line when the strain was on; thirdly, the room was insufficient for wrapping the splice.

The author devised an apparatus as follows: A stiff, square bar 2 ft. 6 in. long, had its sides finished smooth; one end was flattened, and to this end a stiff cross-head about 7 in. long was firmly riveted. One end of the cross-head was provided with a clamp and thumb-screw for holding the wire to be spliced. The other end of the cross-bar had a notch for receiving the ring of a heavy spring balance. A second cross-bar about 11 in. long was fitted with a long socket near its center, so as to slide freely on the long bar. One end of the sliding bar had also a clamp and thumb-screw for holding the opposite end of the wire to be spliced. Through the remaining end of the sliding bar was a hole parallel to the main bar of the machine, through which an eye-bolt passed freely. The eye-bolt had a long thread cut upon it, and carried a hand-wheel with a corresponding internal thread. The hook of the balance passed through the eye of the bolt.

This machine gave plenty of movement for extending the balance, and taking up the slack of the wire, and was very convenient in all contracted places.

According to Mr. Roebling's original notes, an abstract only of which was available, the maximum working strain per wire is 267 lbs., of which 109 lbs., or 41 per cent., is live load, and 158 lbs., or 59 per cent., is dead load. A piece of wire, said to be from the original bridge wire, was tested, with the undermentioned results. The stretch in this and the following tests was taken on one foot of length by a finely divided vernier gauge, having a multiplying lever, and a second vernier for the finer readings.

Diameter of specimen, 0.144 in.; area, 0.16286 square inch. The readings were uncertain up to 200 lbs. strain, owing to inaccuracy in the adjustment of the gauge:

Strain.	Gauge-reading.	Difference.
Lbs.	Foot.	Foot.
200	1.00017	0.00023
300	1.00040	0.00024
400	1.00064	0.00023
500	1.00087	0.00022
600	1.00109	0.00022
700	1.00131	0.00020
800	1.00151	0.00033
900	1.00184	

At 1,260 lbs. the wire broke with a measured set of 0.013 foot. Diameter at point of rupture, 0.110 inch; strength per square inch of full section, 77,365 lbs.

A new splice in a wire when tested gave, under a strain of 300 lbs., an addition of 0.018 in. in length by slip and stretch. Now, in splicing in a new piece of wire, the final splice must evidently be

made under an excess of strain sufficient to compensate for three things: first, for the probable slip in the splice in taking up a working strain; secondly, for the stretch that will occur in the part (about 2 ft. long) contained in the machine while splicing, when it comes under strain; and, thirdly, for the extra strain induced by pulling the wire out from a straight line while splicing.

To determine this excess of strain the following calculations were made:

The slip at the splice is, say.....	0.0180
Taking 200 lbs. as the average strain in a wire with the bridge in use, and 0.00023 foot as the stretch per 100 lbs., the 2-feet length of wire in the machine will stretch $0.00023 \text{ foot} \times \frac{200}{100} \times 2$ feet $\times 12 =$.....	0.0110
Suppose the wire in splicing to be drawn 4 inches from a straight line at the center of 20 feet in length, the additional length required is =.....	0.1332
Total excess of length requisite in making the splice =.....	0.1622

On the supposition that the wrapping around the cables is tight enough to oblige the first 10 ft. length under the wrapping to take up the extra strain, and inasmuch as the wires pass around the shoes, and have, therefore, a double length, the strain would act on about $(12' + 10' + 10' \times 2)$; or, say, 60-ft. length of wire. According to the previous test, to stretch 60 ft. of wire 0.1622 in., a strain would be required equal to

$$\frac{0.1622 \text{ inch}}{12} \div \frac{0.00023 \text{ foot} \times 60 \text{ feet}}{100} =$$

98 lbs.

This would give the strain on the balance as 200 + 98, or, say, 300 lbs.

A balance with 400 lbs. capacity was therefore provided, but on trial it was found that a pull of about 500 lbs. was necessary to ensure a full strain in the wire after completion of the splice. The reasons for this seemed to be, first, that the stretch did not probably reach so far as 10 ft. under the wrapping; secondly, the friction in passing around the shoe had not been taken into account; thirdly, the wires were frequently partially bound by other wires, and the final splice was nearer one end of the free wire than 10 feet.

Another element of uncertainty was the constantly varying load, as the traffic on the bridge is very heavy and subject to rapid and extreme fluctuations. Still another practical difficulty was the fact that, from loosening the strands and removing the clamps and wrappings, the angle made by the unwrapped strand with the round cable was removed 10 ft. farther from the shoes and the several cable wires were no longer equally strained.

For these various reasons it became necessary to assume limits of strain, within which differences would be allowed. As the limit of elasticity of the wire was from 800 to 1,000 lbs., and the extreme working strain 267 lbs., it was evident that if the minimum strain per wire was sufficient, the maximum strain might be largely increased without danger of rupture or inharmonious working. Furthermore, any excess in pull in the sound, new wires would tend to relieve the slightly damaged wires which were not to be repaired. This reasoning, of course, would not apply if carried too far, since an excess of strain introduced into a large number of wires for a considerable length would have changed the curve assumed by the cable.

The minimum fixed upon was 200 lbs. per wire, and was ensured in the following manner: Each wire, as spliced, was marked by a tag, and once a day all the wires were tested by applying a spring balance at the center of their free length, and pulling them out two inches from a straight line. Suppose the balance to then mark 8 lbs., by the parallelogram of forces the proportion $\frac{4}{12}$ inch : 10 feet = 8 lbs. : 240 lbs. = strain of wire. This simple test saved all necessity for immediate inspection of each splice.

Two men could repair from eight to ten wires daily, making two splices in each. They soon found that they were able to dispense with the weighing apparatus, and to judge the tension closely enough by feeling.

A simpler tool was then constructed for holding the wire while splicing. It was made of two bars or legs hinged together, and each bent so as to assume a form much like a pair of pin dividers when they are opened wide, and the pin and point are in position for use. A tightening-rod, with a head at one end and a thumb-screw on the other, passed through the legs at the knuckles. The lower end of each leg was grooved across on each side, and a wedge-key fitted for

clamping an end of the wire to be spliced. Most of the splicing was done with this tool, but the one with the balance was best where the space was contracted.

The total number of wires spliced was four hundred and eighty-four, of which one hundred and seventy-five were in one cable end and one hundred and seven in another. Care was taken to distribute the splices lengthwise, so as not to interfere with the smooth wrapping of the cable. The splices were made by filing the end of the wire to a flat, sloping face of 3 in. length, and so as to reduce the wire at the extremity to about one-third its diameter. The wire was then laid face downwards on an iron anvil, and the convex side nicked for $3\frac{1}{2}$ inches with a tool, having spaces of 0.033 in. to correspond with the diameter of the splicing wire.

After preparing the two ends, they were placed in the machine, the proper strain was applied, and the flat surfaces were brought in contact and tightly clamped by a hand-vice on each side of the center of the splice.

The splicing wire was next tightly wrapped by hand; beginning at the middle of both splice and wrapping wire, and wrapping up to one of the hand vices, then removing this vice to a second and third hold, and each time wrapping up to it. The final finish at this end was given by wrapping $\frac{3}{4}$ in. beyond the filed portion of the wire, and fastening the splicing wire by passing it twice under its own coils. The opposite half splice was finished in the same manner.

The integrity of the splice depends upon the care taken in adjusting the parts accurately to each other, and keeping a constant strain on the splicing wire.

Comparative tests were made of a piece of wire from one of the cables, and of a new splice in the same, and the results are given below.

Diameter of wire=0.144 in., area= 0.16286 square inch. The whole wire behaved as follows:

Strain. Lbs.	Gauge-reading. Foot.	Difference. Foot.
200	1.000050	0 000240
300	1.000290	0.000245
400	1.000535	0.000250
500	1.000785	0.000210
600	1.000995	0.000270
700	1.001265	0.000275
800	1.001540	

At 1,450 lbs. the wire broke with a set of 0.0208 foot on 1 foot. The reduction of area at the point of rupture was 51 per cent. The strength per square inch was 89,015 lbs.

The splice from the same piece of wire gave results as follows:

Strain. Lbs.	Gauge-reading. Foot.	Difference. Foot.
100	1.000390	0.000225
200	1.000615	0.000665
300	1.001280	0.000505
400	1.001785	0.000550
500	1.002335	0.000405
600	1.002740	0.000450
700	1.003190	0.000285
800	1.003475	0.000180
900	1.003655	

At 1,350 lbs. the spliced wire broke with a set of 0.0243 foot on 1 foot. The rupture occurred in one wire at $2\frac{1}{2}$ inches from the end, or 1 inch from the center of the splice, and with a large local reduction in area. In making the test the coils of wrapping wire were left slightly loose at the ends to represent a probable case in actual work.

In comparison with the uncut wire, the splice shows a strength of 93 per cent. Since the splice at one end of each piece of new wire introduced has been subjected to a strain far above the working strain, and the final splice has resisted a pull of at least 200 lbs., it is evident that the greatest possible additional slip would be that arising from the slip at the final splice, due to the difference between a strain of 200 lbs. and a maximum strain of 267 lbs. As this amount, which is very small, must be distributed over about 60 ft. length of wire, it may be neglected.

A piece of new Bessemer-steel wire was tested with the following results:

Diameter of wire =0.147 inch, area = 0.01697 square inch:

Strain. Lbs.	Gauge-reading. Foot.	Difference. Foot.
300	1.000725	0.000200
400	1.000925	0.000230
500	1.001155	0.000345
600	1.001500	0.000125
700	1.001625	0.000230
800	1.001855	0.000280
900	1.002135	0.000270
1,000	1.002405	0.000335
1,100	1.002740	0.000405
1,200	1.003145	

At 1,550 lbs. the Bessemer-steel wire broke with a set of 0.0243 foot on 1 foot.

The reduction of area at the point of rupture was 47½ per cent. The strength per square inch was 90,442 lbs.

The tensile strength of similar sized iron-wire is given by the Trenton Iron Co. at 91,278 lbs per square inch.

Considering that the old wire was more or less damaged by rust, its uniformity of stretch, large reduction, and close approximation in strength, show it to be entirely unchanged by use.

All the wires in a cable having been repaired, the first step towards closing it up was to jar it thoroughly with mallets, and to get out all loose rust and dirt, after which it was thoroughly saturated with raw linseed oil. To reach the interior wires with the oil, a chisel bar had to be forced through in every direction until no uncoated wire could be found. Two days afterward a coating of boiled linseed oil was applied, and then the seizings were replaced on the part of the strands not to be wrapped. The most serviceable tool for compacting the wires of a strand to a round form, prior to replacing the seizing, was one devised for the occasion. It consisted of two semi-circular pieces of iron hinged together at one end of each, and with the free ends bent radially outward. One of the free ends was left longer than the other, and had a hole slotted radially in it, to allow play for the passage of the screw. The other free end was tapped for the screw. The screw had a thread about 4 inches long, and a stem about 1 foot long terminating in a T for convenience in turning. A collar between the screw and stem gave a bearing against the slotted end of the clamp. The interior strands, which were hard to get at, were compacted with this clamp with facility.

The work of bringing the strands together again to the round form of the cable, just within the anchorage, was troublesome but not new. The wrapping of that portion outside the anchorage was at first accomplished with the special wrapping machines used when the bridge was built. As it was impossible to employ these at all points, the ordinary serving mallet familiar to sailors was afterwards adopted, as with care it was found that good work could be effected.

The cable was saturated with white lead and oil in advance of the wrapping. Several coats of the same composition were afterwards applied over the wrapping and strands. Wherever direct vision could not be obtained, the aid of a mirror was found necessary to ensure a perfect covering.

As it would afterwards have been difficult to paint thoroughly that portion of the strands near to where they converge to a round form, it was considered best to protect them by filling for a space of 2 ft. back from the clamp with paraffin. To do this a dam of putty was made across the cable, and the 2-ft. length was surrounded by canvas, into which melted paraffin was poured until when cold the canvas would hold no more. Changes of temperature have thus far had no effect upon the paraffin as a protection.

Experience having demonstrated the imperative necessity of having all parts of the cable accessible for examination, it was decided to leave tunnel-openings around the strands in the anchorages. The bottom of each opening in the masonry was therefore cut so as to drain to an opening in the front wall. The sides were removed to about 6 ft. by 16 feet, and lined with 13-inch brick walls laid in cement-mortar, the cable passing freely through the front wall, with space all around for painting. A jacket was afterwards put on each cable to keep out moisture as far as practicable. As the head-room was insufficient for brick arches, the side walls were capped by an iron box-frame, which was covered by a series of cast-iron plates grated on the upper surface, which surface was at the side-walk grade. The plates were locked together and cemented, to prevent water from dropping on the cables; and the last plate of the series was provided with lifting rings.

In the alternation of mild and extreme cold weather, water of condensation was found to drip from the plates; to prevent this a light wooden frame has been covered with well-painted canvas and placed in the tunnel in an inclined position over the cable. Cork paint may be hereafter applied to the interior of the tunnels.

The only other point of interest was the method pursued in removing the old paint from the cables preparatory to repainting. The necessity of this was made apparent by the cracks retaining moisture after every shower; as it was

reasoned that fresh paint would soon crack in the same lines, and but temporarily cure the evil. Ordinary scrapers were first tried, but were ineffective on account of the gumminess of the paint. This led to the use of cutting-tools such as chisels and drawing-knives, by which to slice it off. By keeping these sharp, the work was fully trebled in quantity over that at first attainable. The average length of large cable cleansed by one man in a day was about 25 ft.

REPORT OF THE ROYAL COMMISSION ON LONDON SEWAGE.

By Capt. DOUGLAS GALTON, C.B., F.R.S.

From the "Journal of the Society of Arts."

The disposal of the London Sewage has been a burning question for the metropolis during the greater part of the last forty years, and it will be convenient in the first place to give a brief historical summary of the various proceedings which have taken place. The present state of the question is principally due to what may be termed the hap-hazard way in which the metropolitan drainage system came into existence. The main metropolitan sewers were originally the streams and brooks which conveyed the water of the higher levels direct to the river; these were the Fleet, the Ranelagh, the Falcon brook, the Effra, &c., &c. There were, moreover, in the low-lying lands of the metropolitan area, which were under high-water level, cuts, or channels, for drainage, which were guarded by sluices in the river bank, to be opened at low water, to allow of the passage of upland water, and closed on the rising of the tide. These cuts, sluices, and brooks, were under the jurisdiction of various local bodies, termed Commissioners of Sewers. As houses spread over the ground between the streams, brooks, and cuts, the natural water-supply diminished, and they became the outlets for the refuse water of the population. The drains from side streets were turned into them; they were gradually covered in, upon no systematic plan; so long as the refuse water passed away out of sight, it did not seem to matter what happened to it. These covered sewers occasionally became choked with deposit, and had to be cleaned out, which seems to have given rise to the idea that sewers should be of sufficient size to be entered by a man for the purpose of cleansing; the idea of a self-cleansing sewer did not prevail in those days. Before the introduction of water-closets, fœcal matter was received in cesspools, which were emptied periodically; but when water-closets were introduced, an overflow from the cesspool was carried into the sewer, and subsequently the water-closets were discharged directly into the drain. When it passed to the Thames, the wide foreshores of which lay in the heart of the metropolis, it formed banks of black, fœtid mud, containing considerable quantities of organic matter of a most putrescent kind. Alternately immersed in water and exposed to the action of air, which, in consequence of its porous condition, it absorbed in large proportion, this mud united all the conditions favorable for the most active putrefactive fermentation, evolving not only gaseous emanations, but diffusing also a large amount of putrescible soluble matter through the river, which supplied additional material to the process of decomposition which was going on in the water itself.

These various evils, taken in connection with the defective construction of the sewers, resulted in producing serious dangers to health. The Metropolitan Sanitary Commission, of which Mr. Edwin Chadwick was a prominent member, was appointed in 1846, and reported in 1848. They recommended a revision of the drainage system of the metropolis, and enunciated the view that the rainfall should be separated from the sewage proper, the rainfall being carried direct to the river, in the old brook courses, and that the drains should be made on new lines, and of a size which would insure a sufficiency of sewage in the drain to cause an adequate velocity of flow, so as to pre-

vent stagnation and deposit. They further recommended the consolidation of the various authorities which dealt with sewers and with roads under one jurisdiction. Other reports from the General Board of Health recommended that the water-supply of the metropolis should similarly be placed under one authority, so that the supply might be more effectually regulated and controlled, both in quality and quantity. These all pointed to the vast importance of creating a united government for London.

The report of the Metropolitan Sanitary Commission led to the consolidation, under the Metropolitan Commissioners of Sewers, of the jurisdiction exercised up to that time by eight separate Commissions of Sewers, but the sewers in the City of London remained under the jurisdiction of the city authorities. Upon this new body devolved the duty of devising a scheme of drainage. In the first place, they obtained that the Ordnance Department should make a survey of London on the scale of five feet to the mile. They did not adopt the views of the Royal Commission as to the separation of sewage from rainfall, but the engineer to the new Commission, Mr. Frank Forster, laid down certain principles of design, and proceeded to prepare plans for intercepting the sewage from the upper districts, and conveying it to the river direct, so as to prevent the flooding of the low-lying districts. He also proposed to intercept the sewage from the Thames within the metropolis, and convey it to points lower down the river. He appears to have completed a design for dealing with the sewage on both sides of the river, but in the long discussions which ensued, his health failed, and he retired, and died. His successor was Mr. (now Sir Joseph) Bazalgette, who was charged by the Commission with the duty of preparing, in conjunction with Mr. Haywood, engineer to the Commissioner of Sewers for the City of London, a plan for dealing with the Sewage of London north of the Thames. In 1855, however, the Metropolis Local Management Act was passed.

This Act vested in the Metropolitan Board of works all the main sewers which at that time were under the jurisdiction either of the Commissioners of Sewers for the City of London, or of the Metropolitan Commissioners of Sewers; but the district sewers were placed under the management of the Vestries, and thus there was no single authority to whom was committed the duty of controlling the whole system of drainage of the metropolis.

The Act went on to enact as follows:—

"Such Board shall make such sewers and works as they may think necessary for preventing all or any part of the sewage within the metropolis from flowing or passing into the river in or near the metropolis, and shall cause such sewers and works to be completed on or before the 31st day of December, 1860."

It was then further enacted that—

"Before Metropolitan Board of Works commence any sewers and works for preventing the sewage from passing into the Thames as aforesaid, the plans of the intended sewers and works, together with an estimate of the cost of carrying the same into execution, shall be submitted to the First Commissioner of Her Majesty's Works and Public Buildings, and no such plan shall be carried into effect until the same has received the approval of the said Commissioner."

It is unnecessary here to follow the detailed proceedings which took place upon this new arrangement; they are given in the "Report of the Royal Commission on Metropolitan Sewage Discharge." It will suffice to state generally that the Metropolitan Board appointed Sir Joseph Bazalgette as their engineer, and that plans were at once prepared.

The main principles upon which the design was based were—(1) the acceptance of the existing state of things involving the removal of sewage combined with a proportion of rainfall, and the rejection of the suggested separation of sewage from rainfall, which would have entailed the consequent construction of a new system of sewers of limited size; (2) the retention of the brook courses as main sewers; (3) the protection, by means of a new system of intercepting sewers, of the low-lying districts from the sewage of the upland districts; (4) the removal of the sewage from the Thames within the metropolitan area, and its conveyance to parts of the Thames outside and below that area.

The main sewers followed generally the lines of the sewers now executed. They

were proposed to terminate, on the north side of the Thames, in an outfall at Barking Creek, and on the south side, in an outfall in the Plumstead Marshes. The cost was estimated at £2,300,000. When these plans were submitted to Sir Benjamin Hall, then First Commissioner of Her Majesty's Works and Public Buildings, he referred the question of outfall to Captain Burstal, R.N., who reported that the northern outfall should be removed lower down the river, at least as far as Rainham Creek, and that the southern outfall should be placed in Erith Reach. The plans were subsequently submitted to three referees, to report their views generally on the proposed main drainage of the metropolis, and on the points of outfall. The referees were Mr. James Simpson, engineer to the Chelsea and Lambeth Water Companies, now dead; Mr. Blackwell, engineer to the Kennet and Avon Navigation, also dead; and Captain Douglas Galton, the author of this paper.

The referees agreed generally with the principles upon which Sir Joseph Bazalgette's scheme proceeded; that is to say, they agreed that a separation of the sewage and rainfall would not be expedient in the case of the metropolitan sewage; that the question of chemical deodorization, or of utilization of the sewage on land, would, under the circumstances, present very great difficulties, and entail a heavier expense than a properly considered scheme for turning the sewage into the Thames at a fitting outfall. But they did not concur in the manner in which these principles were proposed to be carried into effect by the scheme of the Metropolitan Board of Works. Their objections may be summed up as follows:—

1. The scheme did not sufficiently provide for the future; the population of the metropolis in 1851 was about 2,400,000; it has increased regularly by one-fifth in every ten years since the beginning of the century, and in 1881 it amounted to nearly 4,000,000; in 1901, at this rate of increase the population will amount to about 6,000,000. The scheme of the Metropolitan Board only provided for a prospective population of 3,255,000, and the referees objected that, on that account, and on account of the limited provision it made for the removal of rainfall, the sewers would frequently overflow into the Thames, and that the low-lying districts would be liable to be flooded.

2. That the scheme of the Metropolitan Board would remove by complete gravitation the drainage of only 27 square miles, out of 118 square miles, to the outfalls at Barking and Plumstead, and the drainage of 31 square miles would be lifted once, and the drainage of 43½ square miles would be lifted twice, whereas, by constructing the tidal channels for the removal of the sewage as suggested by the referees, all the sewage which would flow to a point five feet above Trinity high water mark near the metropolitan boundary, that is to say, the drainage from 81 square miles of the metropolitan area could have been removed by gravitation to Sea Beach.

3. That the proposal to turn the metropolitan sewage into the Thames, near Barking, or even at the outfalls in Erith Reach, suggested by Captain Burstal, would not prevent the sewage from returning within the metropolitan limits, and would be injurious to the eastern districts of the metropolis which lie adjacent to the Thames, the population of which was rapidly extending.

4. The referees consequently proposed that the sewage should be taken to a point on the north side of the Thames between Mucking Lighthouse and Thames Haven; and on the south side to Higham Creek in the Lower Hope, because the strength of the current at both of these places is sufficient to prevent any deposit of materials brought down by the sewage; and the great expanse of water, the continual accession of clean tidal water, and the rapidity of current would ensure the mixing of the sewage with water under the most favorable circumstances, and at a point where the shores were almost uninhabited. The referees added that these were the only places in the river, either above or below, which entirely fulfill the conditions essential to the object in view.

5. The referees were not, however, satisfied with the removal of the sewage to a point lower down the river, but contemplated uniting with the removal a form of purification. Instead, however, of deodorization by chemicals, they proposed the principle of partial purification by dilution and movement during the flow of the sewage through the outfall

channels for a distance of nearly twenty miles. To effect this, they proposed that there should be added to the sewage, at the head of the outfall channel, a volume of water direct from the Thames, at high water, equal to six times the then estimated dry weather flow of the sewage.

6. The referees estimated the total cost of the intercepting and collecting sewers within the metropolis, and of the outfall channels, at £5,438,000, of which about £2,250,000 was the cost of the outfall channels.

Upon this report of the referees, the Government declined to sanction the plans of the Metropolitan Board of Works; a long correspondence ensued, and during the discussion the Liberal Government then in office was succeeded by a Conservative Government, and Lord John Manners became First Commissioner of Her Majesty's Works. The new Government passed an Act of Parliament, in 1858, relieving the Metropolitan Board of Works from the necessity of obtaining the sanction of the Government to their scheme of drainage, or to the position of the outfalls, on the ground that as the metropolis paid for the works, they had a right to construct them in any way they thought fit. This doctrine was sound so far as the sewers within the metropolis are concerned, but it was most unsound, short-sighted, and unstatesmanlike in respect of the outfalls outside the metropolitan area, because upon the position of the outfalls depends the condition of the Lower Thames—that great navigable highway—in the length of which the metropolis occupies but a comparatively small portion. It is, however, clear, from the discussion which took place in Parliament, that it was intended that the sewage should be deodorized at the outfalls; and should not be turned into the river in a crude state.

This oversight of the interests which the public at large, independent of the metropolis, have in the Thames, was attempted to be remedied twelve years subsequently by the Thames Navigation Act of 1870, which provided that the Metropolitan Board of Works should, at their own expense, keep the Thames free from such banks or other obstructions to the navigation thereof as may have arisen or may arise from the flow of sewage at the outfalls, for the time being, into the river; but this Act makes no mention of the necessity of maintaining the purity of the Thames water, or of conditions which might affect health.

Upon the passing of the Act of 1858, the Metropolitan Board of Works proceeded to construct their sewerage system, which was estimated to cost somewhat under £3,000,000. The northern and southern outfalls were completed and in use in 1864, and the main drainage system was formally opened by H. R. H. the Prince of Wales, in 1865. The works are stated to have cost about £4,600,000, but no provision was made for deodorization, the crude sewage being turned into the river at the outfalls.

It is also to be observed that the criticism of the referees upon the limited provision for carrying off the sewage made by the Metropolitan Board have been subsequently fully justified. In the report of the Metropolitan Board for 1881, occurs the following paragraph:

"The floodings of heavy rains which have occured on several occasions, in recent years, in some of the populous districts of London, principally those on a low level, made it necessary for the Board to determine upon the construction of some additional sewers to carry off the storm water. The cost of these additional works is mentioned at £1,000,000.

The report further says:

"The Board has lately resolved to enlarge the reservoirs at Barking and Crossness outfalls, to 50 per cent. beyond the present capacity, to admit of the largely increased quantity of sewage being stored until the ebb tide, instead of, as have been occasionally necessary, having to be discharged on the flood tide, and thus giving rise to complaints that the Thames water at Woolwich was impure."

And the Royal Commissioners on Metropolitan Sewage Discharge report that these extensions will bring the total expenditure to £6,250,000, without any works for deodorization, as against the £5,438,000 stated by the referees to be necessary.

Whilst these large works were going on under the Metropolitan Board, it may be said that the whole system of minor sewerage and drainage in the metropolis was also undergoing revision, and considerable efforts have been made, by the use of catch-pits and by regulation, to

prevent road grit passing into the sewers. The subsidiary drains may be said generally to have been to a considerable extent changed from being sewers of deposit into self-cleansing sewers, although no doubt instances to the contrary may still exist.

In the central districts of the metropolis the extensive foreshores of the river, with their banks of mud, have been much diminished by the construction of the splendid embankments which extend on the north from Blackfriars, to above Chelsea, and on the south from Westminister to Vauxhall. In other parts wharves have been raised to prevent the overflow of high tides. The general result of these works must be judged by the health of the population. If the death-rate be accepted as a test, it is noteworthy that the average death-rate of the decade 1841-50 was 24.8 per 1.000. If the conditions had remained *in statu quo*, except as to increase of population, the death-rate of 1871-80 ought to have been 26.2, according to Dr. Farr's tables for increase due to density of population. In point of fact it was only 22.5. It may be contended that this is too high; but at any rate the diminution may fairly be put down to improved sanitary conditions, amongst which the drainage system stands prominently forward.

But in looking back at the history of the sewage question it seems astonishing that good results could have emanated from the arrangement made in 1855. That arrangement abolished uniformity of control over the main roads of the metropolis; and whilst it gave the jurisdiction over main sewers to the Metropolitan Board of Works, it placed the district sewers under the control of separate Vestries; the control of the water supply remained in the hands of eight different companies. If there is one thing more certain than another, it is that a uniform control is especially necessary in the drainage and water supply of a district; the control over the sewerage especially should exist from the reception into a public sewer of the sewage from the house drain until it reaches the point of outfall. In the metropolis, Parliament has done its best to prevent uniformity, and to prevent the Metropolitan Board of Works from having a fair chance. If there had been such uniformity of control over the water supply and drainage, the quantity of water consumed, and consequently of sewage, might have been more effectually regulated: and if the details of the district drainage had been under one and the same authority as the main sewerage, it is quite possible that inasmuch as the conditions of the districts vary, so the sewerage might have been arranged in special cases on somewhat different lines. It is conceivable that in some parts, sparsely occupied, the separate system might have been to some extent introduced, although it was inadmissable in the more densely inhabited portions of the metropolis.

There have been now three public inquiries into the evils alleged to arise from the sewage discharge at the outfalls at Barking and in Erith Reach. The first was by Sir Robert Rawlinson in June, 1869, upon a complaint from the inhabitants of Barking that the river was silting up so as to affect the navigation, and that the pollution was dangerous to the health of the inhabitants of Barking. Sir Robert Rawlinson reported the allegation to be only partially proven, adding that the unsanitary condition of the town of Barking prevented the inhabitants from being in a position to establish deterioration of health from the London sewage, and that the main channel of the Thames had not been reduced; but that the Thames is polluted by the metropolitan sewage, and that deposits of mud had taken place on the shores of Barking Creek, but from what cause had not been proven.

The second inquiry was by means of an arbitration, under the Thames Navigation Act of 1870, between the Conservators of the Thames and the Metropolitan Board of Works. The Conservators of the Thames contended that certain mud banks had resulted from the discharge of sewage at the outfalls, and had injured the navigation. The arbitrators determined that the Barking and Halfway Reaches, in which the banks are situated, were better for navigation than when the outfalls were opened. That the banks had arisen from dredging operations carried on by the Conservators of the Thames, or sanctioned by them, such dredging having affected the direction of flow of the currents and altered the sectional area of the river.

The third inquiry was that recently

held by the Royal Commission on Metropolitan Sewage Discharge, which was directed to ascertain whether any evil resulted from the discharge of sewage into the Thames by the Metropolitan Board of Works, and if so what measures could be applied for remedying or preventing the evil. The report shows generally that the pollution of the river arises from the large volume of the sewage thrown into it, in a locality where the area of the river is small in comparison to the volume of sewage discharged into it. The referees estimated that the total quantity of sewage from the metropolitan area discharged into the Thames in dry weather amounted, at the time of their inquiry, viz., in 1857, to 15,250,000 cubic feet per day. The population, which was then about 2,500,000, has now increased to something between 3,800,000 and 4,000,000, and in the report of the Royal Commission the volume of the dry weather sewage is now stated to amount to 23,000,000 cubic feet per day, which is an increase very nearly proportionate to the increase of population. The report of the Royal Commission states that the low water area of the river near the outfalls is about 30,000 square feet, and that this volume of sewage would fill a length of about 750 feet of the river at low water. At the present rate of increase of the metropolis, the population will amount to 6,000,000 in 1890, and at a proportionate rate of increase the sewage will amount to nearly 35,000,000 cubic feet per day.

It must not, however, necessarily be assumed that the volume of sewage will continue to increase in the same proportiton as hitherto, inasmuch as care in regulating the water supply would materially reduce the dry weather flow of sewage in London, as it has in Liverpool, Manchester, and other towns; but this seems to be one of those questions which must wait until the Government of London has been consolidated under one jurisdiction.

The Royal Commission report that "we find it impossible not to be satisfied by the overwhelming amount of concurrent evidence as to the real existence, under certain conditions, of the nuisances complained of." The foreshores in the reaches near the outfalls are covered with black, fœtid mud in a highly putrescible condition, just as was the case with the foreshore in the heart of the metropolis before the construction of the intercepting sewers or of the embankments; they also report "that the fish have disappeared from this point of the river, and that their disappearance is due either directly or indirectly to the sewage discharge." They further report that the evils of the present system of discharging the metropolitan sewage are decidedly such as to require a remedy, and that the public interests require that such a remedy should be applied with the least possible delay.

Before proceeding further, it may be remarked that the report of the Royal Commission, just issued, is a model report, in so far that it is drawn up with great skill and care, and forms the most valuable survey of the state of the question on water-carried sewage disposal which has ever yet been issued.

In order to appreciate the effect of turning in the large mass of sewage into the river in a concentrated form, it is necessary to note the influences exercised by the sewage upon the river. The report of the Royal Commission shows that although the outfalls are at Barking and Crossness, and the sewage may be assumed to be turned into the river only on the ebb tide, yet the float experiments showed that at whatever time of the tide the sewage is discharged, some of it may, under certain conditions, be carried up by the tidal oscillation alone into the heart of the metropolis, and even further. The report states that, in fact, the chemical analyses show that there is a progressive increasing impurity of the river from Teddington downwards to the outfalls, and then a decreasing impurity to Gravesend, beyond which place the sewage is not perceptible. As regards the impurity in the metropolis above the outfalls, it must, however, be recollected that on most rainy days sewage is allowed to flow through the storm overflows into the river in the metropolis, and, moreover, sewage also passes into the Thames in the tidal estuary above the metropolitan area. The oxygen dissolved in the water exhibits a corresponding decrease as the sewage increases, and *vice versa*, which shows that the oxygen does active work in oxidizing, and thus purifying the river from sewage impurity; in addition to the effect of

oxygen, purification is assisted by animal and vegetable life. Thus, the sequence may be summed up as, first, pollution by sewage; second, oxidation of the sewage; third, consumption of the sewage by minute animals, by the re-oxygenation of the river by means of animal and vegetable life, and by renewed absorption of oxygen from the air, which is favored by the movement of the water by tide and wind.

The larger the volume of tidal water in proportion to the sewage, the more rapid is the effect of these processes. An interesting series of experiments which Dr. Tidy made in 1878 and 1879 corroborates this view. They are recorded in a paper read before the Chemical Society in May, 1880. He mentioned one case where a liquid, containing one part of sewage to twelve of water, flowed a distance of one mile in nine hours; the oxygen required to oxidize the organic matter was .538 grains before the experiment, as compared with .187 grains after the experiment, showing as the result of one mile flow a diminution of .351 grs. of the oxygen required. The organic carbon, organic nitrogen, and chlorine were also materially diminished. Dr. Tidy recently remarked upon these experiments, "I am certain that, given a dilution of one-seventh sewage and six-sevenths fresh water (fully aerated, *i. e.*, containing two cubic inches of oxygen per gallon), with a flow of two miles per hour, not a trace of noxious matter would be found at a distance of five miles." It is worthy of remark that, at the places suggested by the referees for the discharge of the sewage, viz., opposite Mucking Lighthouse, the low-water area of the river is 191,000 square feet, and the high-water area 304,000 square feet; moreover, the sewage, as proposed to be diluted by the referees, would, after its course of twenty miles along the outfall channels at a rate of nearly two miles per hour, have reached the river in a condition much more favorable for dispersion than is the crude sewage turned in at Barking and Erith. And there can be no doubt but that if the suggestion of the referees had been adopted, the question of the pollution of the Thames by the metropolitan sewage discharge would not have arisen in the present generation.

In proposing a remedy, the Royal Commission accept the general principles which have guided the design of the metropolitan sewage system. They recognize the difficulties which have been felt of separating the rainfall from the sewage in the metropolis, difficulties which have been equally felt by all the various authorities who have hitherto been consulted on the subject. They state that it is neither necessary nor justifiable to discharge the sewage in a crude state into any part of the Thames. In considering how it should be dealt with, the Commissioners received a large amount of evidence on the different methods of sewage purification, as, for instance, treatment with lime, with perchloride of iron, by means of the A B C process, the filtration through limited areas of land, broad irrigation, &c. Col. Jones suggested that the sewage should be conveyed to Canvey Island, and then allowed to deposit in shallow cuts without the use of chemicals, the liquid, when clear, being run into the river.

There are two points connected with the London sewage which do not seem to have been sufficiently taken into account in many of these proposals. The first is that the time which necessarily elapses before the sewage reaches the outfall precludes it from being in so favorable a condition for treatment or utilization as fresh sewage would be. The second, that the degree of purity which should be required in an effluent depends on the degree of purity of the water into which it flows. The first of these, viz., the condition of the sewage when it reaches the outfall, has an important bearing upon the extent to which treatment with lime will prove advantageous, for in proportion to the freshness of the sewage is the efficiency of the lime process. The degree of freshness of character of the sewage has also an important bearing upon the utilization of the sewage on land, and the prospect of deriving profit from the constituents. This part of the question has not, indeed, advanced much during the last twenty-five years; the remarks of Messrs. Hoffmann and Witt, in their report to the referees, are nearly as applicable to-day as they were in 1857, viz., "notwithstanding the variety of patents which have been taken out, the problem of recovering profitably the valuable constituents of sewage re-

mains unsolved. The valuable constituents of sewage are like the gold in the sands of the Rhine, its aggregate value must be immense, but no one has succeeded in raising the treasure."

After weighing very carefully the evidence which they received on this part of the question, the conclusion at which the Commission arrive is practically the same that has been arrived at in previous inquiries, viz., that the metropolitan sewage had best be got rid of at the smallest cost compatible with efficiency. The Commission state that the suspended solid matters in the sewage are the chief causes of nuisance, and that by precipitation the suspended matter may be almost entirely removed, and the tendency to deposit largely lessened; but that the result of discharging an effluent alkalized by lime into the river at the present outfalls is problematical; they think, however, that lime would probably be as good as any other chemical for purposes of precipitation. The Commission add—

1. That a process of precipitation would effect an improvement on the present state of things. It would lessen the tendency to deposit foul banks and shoals.

2. That precipitation alone would not finally purify the river; nuisance would still occur in dry weather. That the injury to fish and danger to wells would still remain.

3. That the precipitation works themselves might be carried on without sensible nuisance.

4. That the cost of the precipitation would be at least £200,000 a year, or 1s. per head of the population.

5. That it would result practically in the loss of a large part of the manurial value of the sewage, offering no prospect of future realization, except by applying the clarified liquid to land.

For these reasons, and apparently also because a precipitation process could be brought into use more quickly than any other remedy, and if disused would entail a comparatively small loss of capital, they conclude that some process of deposition or precipitation should be applied to the London sewage at the present outfalls. The sludge would be either applied to the raising of low-lying land (it is to be hoped not to serve for the foundations of future dwellings); or burnt, or dug into land, or carried away to sea. The liquid portion would be, as a temporary measure, allowed to escape into the river. The report goes on to say that, as a permanent measure, this liquid must be further purified by being passed through land, or else must be carried down to Hole Haven.

According to the experience of Birmingham, which is not a water-closeted town (that is to say, only one-eighth of the houses have water-closets), the amount of land necessary for the metropolitan sewage, after treatment with lime, would be 6,000 acres, and the cost of the capital outlay for land and necessary works for the metropolis, upon the basis of the Birmingham expenditure, would apparently be fully £1,500,000. Mr. Bailey Denton states, however, in his most recent publication, that one acre of suitable land properly prepared would purify the clarified sewage of 2,000 persons; upon that basis at the present time the clarified sewage of the metropolis would require about 2,000 acres of land. The preparation of the land varies in cost, according to Mr. Bailey Denton, from £30 to £150 an acre. The Commission estimate the annual expenditure for precipitation by lime alone, on the present population, at £200,000 a year, which represents a capital sum of about £6,000,000, at $3\frac{3}{4}$ per cent.; or assuming that a rental could be got for the land of from £6 to £8 per acre per annum, it would still stand against the metropolitan ratepayers at £4,500,000. This estimate, however, appears to be based only upon the present dry weather flow of about 23,000,000 cubic feet of sewage for twenty-four hours. But in times of rain the sewers are capable of bringing down more than three times that quantity to the reservoirs, the excess would apparently flow direct into the river, and this probably on about one day in three. It may be observed, in passing, that whilst the dry weather sewage contains on an average 23.36 grains of solid matter per gallon, of which 9.44 is mineral, and 13.92 is organic matter; in wet weather, when rain is intermittent, the sewage may contain from twice to five times this quantity of solid matter, of

which no doubt the larger part is mineral, but the organic matter is also very largely increased. In continuous wet weather, on the other hand, the sewage may become abnormally weak. The recommendations of the Royal Commission will not, therefore, deal thoroughly with the question, as in wet weather a large quantity of sewage will still pass in a crude form into the river. Moreover, according to the rate of increase of the metropolis, the sewage will amount to 35,000,000 cubic feet in little over twenty years. The cost of settling beds and land for purification, as well as the annual cost of the purification, will have to be increased in proportion, and, therefore, the question may be fairly raised whether it will not be a serious waste of money to adopt so expensive a palliative. And if the final result of the deodorization and filtration through land is to return a portion only of the effluent purified to the river, at a cost equivalent at the present time to a capital outlay of of £4,500,000, which will amount up at no distant date, with the increase of population and consequent sewage, to £6,000,000, in addition to the immediate expenditure of probably £1,500,000, for land and works, might it not be simpler and cheaper, even now, to adopt the plan of modified deodorization suggested by the referees, viz., dilution of the sewage, combined with its flow through many miles of long tidal channels, at a cost of two and a-quarter millions or less.

It will be apparent that one of the principal difficulties of the sewage question in the metropolis arises from the concentration of so vast a quantity of sewage, which is carried down to the outfalls and turned into the river at two points near each other. Sir Joseph Bazalgette, in his evidence before the Royal Commission, contemplates an extension of this amount of sewage, by bringing into one scheme the sewage from the valley of the Lea up to Hertford, and the Thames valley sewage, with its tributaries, from Leatherhead, Epsom, Ewell, Cheam and Sutton.

There is no doubt that the question of the disposal of the sewage of the metropolitan area is only one part of the subject, and that the whole question of the disposal of the sewage of the valleys of the rivers Thames and Lea requires to be taken into account and dealt with in a comprehensive manner. And this subject must daily increase in importance as inducements are held out to the working population of London to reside in more airy localities outside London; and to come up daily to their work; for it is certain that, unless this question of the disposal of the refuse water of these outlying districts is taken in hand earnestly and zealously, the community will in a few years find itself in a much more difficult position than it is now placed in by the question of the metropolitan sewage alone.

It is clearly not advisable to allow the sewage from outlying districts to flow through the heart of the population of London. The referees, in their report, especially alluded to this point. They said: "It is desirable, as far as possible, to prevent the sewage from flowing through the thickly inhabited districts of the town;" and so strongly were they impressed with this view that they recommended "that the low-level sewage west of Somerset House should be carried back to opposite Battersea, and then across the river, to be there raised into a southern high-level sewer," passing through a comparatively sparsely inhabited district, instead of passing as it now does, through the most densely populated part of London.

This brings us to the question as to whether the limits of concentration have not been fully reached, so far as the metropolis and its subsidiary districts are concerned. Indeed, it could be argued, with some show of reason, that it might have been advisable to have adopted, in some parts of the sparsely inhabited western districts of the metropolis, in a modified form, the separation of sewage and rainfall, and possibly to have refrained from pumping twice over the sewage of the districts of the western portion of the metropolitan area, in order to convey it through the heart of the more populous parts of London to Barking or Crossness; and instead of this to have resorted to some form of purification. In the present state of the question, this is only a reflection which occurs as to what might have been best with our present experience if the field were clear.

But with respect to the sewage of districts outside the metropolis, the subject is largely one where future action is less fettered by former proceedings. No doubt, even if it were admitted as an axiom that sewage of outlying populations should not be allowed to flow through densely inhabited districts, yet it is possible that sewers might be arranged to carry the sewage from the places in question to the sea. But is this necessary, or is it desirable? If sewage from places in the Thames Valley above the metropolis, or from the valley of the Lea, is required to be taken to the sea, where are we to stop? The difficulties of the sewage question arise from concentration, and it is therefore a much more rational solution to give up the idea of concentration, and to require each district to make arrangements for the disposal of its own sewage.

If a population concentrates itself on a limited area, it must make arrangements for the wants entailed upon it by that concentration. For instance, it must provide streets to give access to the houses; it must provide open spaces in which to marshal the railway trains which bring in the food or other articles which minister to the daily wants of the population. It must provide gathering grounds for its water supply, parks for recreation, and open spaces in which to bury its dead. Similarly it is equally necessary that every nucleus of population should provide open spaces on which to purify its sewage without being offensive to the neighboring houses.

The report of the Royal Commission makes it abundantly clear that whilst profit must not be expected from sewage utilization, yet that precipitation and utilization are eminently fitted, when properly applied to produce a purified effluent; and, therefore, that were certain conditions of population and of sewage always observed, each district could be made self-contained in respect to its sewage just as it can be in respect to its cemetery.

1. The conditions of population are that the district should be limited in numbers and in the area occupied.

2. The conditions of the sewage are—(*a*) the extent to which the sewage can be separated from the rainfall; (*b*) the degree of freshness of the sewage, as received at the place where it is treated.

In the case of the metropolis it may be accepted that the removal of sewage and rainfall was a necessity, and in this view all the practical authorities who have considered the subject appear to concur. The reasons for combining sewage and rainfall are not always equally strong, and in many cases the strength of the argument is against combination. But no absolute general law can be laid down that sewage should invariably be separated from rainfall. On this question each locality must be governed by the circumstances of the case; but there can be no question that the problem of sewage disposal would be simplified almost in direct proportion to the extent to which the separation of sewage from rainfall can be carried with prudence. The difficulties of separation lie in the numerous foul surfaces which prevail in towns, and especially in streets of large traffic, in which, in proportion as the road surfaces are rendered smooth and impervious, so does the mud and the dust appear to consist chiefly of horse manure, and this could only be prevented by the adoption of a much more perfect system of street cleansing than prevails at present.

The importance of the report of the Royal Commission lies not so much in what it recommends for the metropolis, as in the valuable information which it has collected on the present state of the general question of sewage disposal—information which is applicable to the wants of the whole country. The comprehensive manner in which the subject has been treated is of especial value at the present time, because the country is becoming too closely built over for this question to be allowed to remain any longer in the *laissez faire* condition which it has hitherto occupied, if regard is to be had to the purity of the air, the purity of the soil, or the purity of the rivers and watercourses.

TRACING paper may be made by immersing best tissue paper in a bath composed of turpentine and bleached beeswax. A piece of beeswax about an inch in diameter, dissolved in half a pint of turpentine, is said to give good results. The paper should dry two or three days before use.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—FEBRUARY 18TH, 1885.—Vice-President G. S. Greene, Jr., in the chair. Discussion on the paper by E. Sweet, M. Am. Soc. C. E., on the Radical Enlargement of the Artificial Waterway between the Lakes and the Hudson River was continued.

Mr. E. S. Chesbrough, Past President Am. Soc. C. E., by letter, considered it advisable to make the surveys and estimates recommended by Mr. Sweet.

Mr. Walton W. Evans, M. Am. Soc. C. E., said that when speed was not brought in as an element, no railway can stand in competition with a well constructed water line. Statistics show the influence of the Erie Canal on railway freight charges. The best policy for the State of New York will be to enlarge and improve this waterway. He referred to the fact that Gouverneur Morris was the projector of the Erie Canal. He suggested the possible use of elevators instead of locks, and the use of preserved wood in many places instead of stone.

Mr. T. C. Clarke, M. Am. Soc. C. E., said that the cost of repairs and the interest on the amount to be expended in making the proposed improvement would be very large. The canal would be shut half the year by ice. The railroads are always ready. Hence the fact that the canal carries so small a portion of the freight.

Mr. N. M. Edwards, M. Am. Soc. C. E., estimates that with the proposed waterway wheat could be carried from the head of the lakes to New York City for 5 cents a bushel, with 1 or 2 cents added if tolls are required. He compared the possible rates by various routes, and considered that the advantages of the proposed enlargement should command recognition.

Col. Wm. E. Merrill, M. Am. Soc. C. E., considers the chief merit of the project to be, that it will reduce the cost of wheat to a theoretical minimum; the benefit of such a radical cheapening of the chief article of human food is beyond calculation. He considers the project entirely practicable. The current would be somewhat objectionable, but in favor of the heavy traffic. He suggests fixed dams on the Mohawk rather than movable dams. The great military advantages of such a ship canal should not be overlooked.

Mr. John D. Van Buren, Jr., M. Am. Soc. C. E., compared two routes for a ship canal within the State of New York and two which would be international—those from Chicago to New York, by Buffalo and the Erie Canal, by the Welland Canal (or a similar canal on the State side) and Oswego, by the St. Lawrence and proposed Caughnawaga Canal and by the proposed Ottawa and Caughnawaga Canals.

The Oswego route is deficient in water. The Ottawa route is a day shorter in time than the Erie. It is an important question whether the advantages of the international route would outweigh the importance of having the route entirely in the State.

Basing an approximate estimate upon the cost of the present Erie Canal, Mr. Van Buren makes a grand total of $194,000,000 as the probable cost of the proposed Erie Canal route, which, with interest during ten years of construction, would amount to $240,000,000. This is about three times the estimated cost of the Nicaragua Canal, and more than three times the actual cost of the Suez Canal.

The true test for a proposed government or private work is the commercial one, Will it pay? Unless the cost of transportation would be materially reduced below the cheapest present normal rates the enterprise would prove a failure and no benefit. Taking a probable interest charge and an annual expense for repairs and management at the same sum as that expended on the Suez Canal, and a total tonnage of 20,000,000, Mr. Van Buren estimates the charge for the support of the canal at 3 cents per bushel of wheat from Buffalo to New York. Looking at the matter as a private interprise, the conclusion is reached that a private company would hardly dare undertake the work.

Considered as an undertaking by the general Government, the question is, What interest, under the Constitution, has the Federal Government in such a project? It would be difficult to induce Congress to appropriate funds for an improvement likely to seriously damage the interests of neighboring States.

Considered as a State enterprise, it must be as a free canal. The general benefits would be those attending a great increase of business. The people of the State would have to pay about $16,000,000 per annum.

Mr. D. Farrand Henry, M. Am. Soc. C. E., said that the question was not solely how to reach New York, but how to reach Liverpool. Three routes have been proposed: from Chicago to the Mississippi by the Illinois River; the enlargement of the Erie Canal; the deepening of the Welland Canal, and the improvement of the St. Lawrence. Comparing these routes, the conclusion is reached that the latter is decidedly the most feasible.

Mr. O. Chanute, M. Am. Soc. C. E., suggested that the question should be considered whether it may not be practicable to apply some form of heat engine, different from any heretofore tried, for the propulsion of the boats on the present canal, and thus secure economy and speed and large carrying capacity for the canal, as compared with the great interest charges on the waterway proposed by Mr. Sweet.

Mr. C. Herschel, M. Am. Soc. C. E., discussed the regulation of railroad freight rates by the encouragement or the creation of water competition, rather than by a reliance wholly upon the work of railroad commissioners, or upon the successful enforcement of rigid statutes designed to forbid excessive and discriminating freight rates, under pains and penalties.

Mr. Theodore Cooper, M. Am. Soc. C. E., did not consider that freight could be taken economically by the same vessel from Chicago or Duluth to Liverpool. The vessel constructed properly for ocean navigation would not be suitable for the canal or the lake. The vessel constructed to carry freight economically on the lakes is not fit for ocean voyages.

Mr. J. Nelson Tubbs, M. Am. Soc. C. E., by letter, expressed doubt of suitable provision for water supply on the long levels of the proposed canal, as the evaporation and percolation would be very great.

Mr. E. Sweet, M. Am. Soc. C. E., considered the various points that had been brought forward in the discussion. He gave figures to show that the losses by percolation and evaporation could be supplied from Lake Erie by a current of about six-tenths of a mile per hour. This current would increase going eastward till reaching the long level, across which it would not exceed three-tenths of a mile per hour. It would be in the direction of the heavy traffic and a benefit rather than a hindrance to navigation. He stated that the estimates of Mr. Van Buren proceed from erroneous premises as they assume the cost of the present canal at about $49,000,000, which is fifty per cent. more than its actual cost as shown by the State records. These show that the enlargement between 1835 and 1862 cost $31,834,000. The structures of the original canal were discarded in the enlargement, and its route was almost as generally disregarded as the route of the present canal is in the proposed ship canal. The cost of the original canal should not, therefore, be considered in such an estimate. But, even adding this to the cost of enlargement, and all the interest of all the loans for constructing and enlarging the canal, the sum assumed by Mr. Van Buren is not reached. Taking the actual cost and applying the principles he adopts, the estimate becomes $127,000,000. Three per cent. interest charges are more probable than the five per cent. assumed by Mr. Van Buren. The interest charge would thus be $3,810,000 instead of $12,000,000. He also estimates maintenance too high.

The suggestions favoring the adoption of the St. Lawrence route, apart from the questions of State and National interest and patriotism, simply would by that location aid foreign commerce and defeat the chief object of the proposed improvement which is to facilitate the vast domestic traffic between the East and the West. Its tonnage is now many times that of the foreign commerce tributary to either route, and the disparity will surely increase with the facilities proposed.

The suggestions of Mr. Chanute would not result in the speed desired. The essential defect of small canals is that the boats must have too large an immersed surface for the tonnage they carry, and thus enormously larger resistance per ton than large vessels.

Replying to Mr. Corthell, Mr. Sweet said that while the railroad is the most important instrument of internal commerce, it has limitations of capacity and economy. The limitations of economical water carriage are quite different. The economy of water transit increases with the size of the vessel, and the capacity of artificial waterways increases nearly as the cube of their depth of channel.

Mr. Sweet also showed that a speed of five miles per hour could easily be realized by large vessels in the proposed canal from Buffalo to Utica, and of ten miles per hour from Utica to New York. This, with proper allowance for detentions at locks, would give a duration of voyage from Buffalo to New York of 85 hours.

MARCH 4TH, 1885.—President F. Graff in the Chair.—The vote on the proposed amendment to the Constitution was canvassed as follows:

For the amendment	181
Against the amendment	28
Blank votes	3
Ballot not endorsed	1
Total votes received	213

This proposed amendment, having received an affirmative vote of two-thirds of all the ballots cast, was declared duly adopted as an amendment to the Constitution of the Society. It read as follows:

Add at end of Article XXII:

Any member of the Society, not in arrears for dues, may compound for the payment of all future annual dues, except as hereinafter provided, by the payment of two hundred and fifty dollars.

Provided, That all resident members, or those who may hereafter become such, shall be and remain liable to the annual payment of the difference between the annual dues of resident and non-resident members, as the same now is, or may be established from time to time; but any member may at any time compound for the future payment of all annual dues of every nature and kind, by the payment of seventy-five dollars in addition to the two hundred and fifty dollars hereinbefore provided for.

Provided, however, that each person duly elected a member shall pay the entrance fee and also the annual dues for the current year of his election.

Provided, also, that any member desiring to compound for future annual dues shall have paid the annual dues for the current year before the compounding sum may be available.

Members compounding shall sign an agreement that they will be governed by the Constitution and By-Laws of the Society as they are now formed, or as they may be hereafter altered, amended or enlarged; and that in case of their ceasing to be members from any cause whatever, the amount theretofore paid by them for compounding, and for entrance fees and annual dues, shall be the property of the Society.

All moneys thus paid in commutation of annual dues shall be invested as a permanent fund, the interest thereof only being subject to appropriation for current expenses.

ENGINEERS' CLUB OF PHILADELPHIA—FEBRUARY 21ST, 1885.—President J. J. de Kinder in the chair.

The Secretary presented, for Mr. Henry A. Vezin, a set of Diagrams for Determining Belts and Pulleys and Shafts, with a description thereof. They were derived from Wieber's Skizzenbuch fur den Ingenieur, but modified by Mr. Vezin to suit our units of weight and measure, and their application extended. They present the usual advantages of the graphic method; not only saving the time and mental exertion necessary to calculate by formula, but also presenting a picture of possible and desirable modifications of design.

He also presented similar Diagrams for Cast Iron Cogs.

Mr. J. Milton Titlow contributed a paper, illustrated by drawings and photographs, upon the Strengthening the West Main Abutment of Chestnut Street Bridge, Philadelphia.

The bridge is 42 ft. wide, with two cast iron arched river spans of 185 ft. each, supported by heavy abutments on the shores: on the west are two segmental brick arched spans, of 60 and 53 ft., to two long retaining walls, holding the earth supporting the roadway.

The whole of this west approach is located upon what was called the river flats, partly occupied by wharves and docks, and resting piles from 24 to 40 ft. in length, driven through a stratum of river mud or silt from 16 to 20 ft. in thickness, to the coarse gravel with boulders and cobble-stones lying upon the bed rock.

The masonry was practically completed in 1865, about a year before the cast iron river spans; and any movement of the main abutment, by reason of its maintaining its verticality, transferred a horizontal thrust to and through that part of the approach in the rear, shown by a depression of the river spans, a shortening of and a rising of the crowns of the arches in the rear of the main abutment, and a closing of the joints of the copings on spandrel and retaining walls, as well as pushing back the small approach abutment at the springing line between the retaining walls. This rising of the west arch became very apparent in 1879, when horizontal wooden struts were placed above the platforms of foundations for the purpose of taking up and transferring this horizontal thrust to the retaining walls, making them act as buttresses temporarily until a plan could be determined upon, which should be effective in itself.

Of the several designs suggested for cylindrical iron buttresses, that of J. F. Anderson was adopted, having the great advantage of facility of construction in the small space at our disposal, the archway being occupied by a double track railroad and two sidings, to remove which would probably equal one-half the cost of intended work. This design, as executed, consisted of placing, by means of compressed air, four wrought iron cylindrical buttresses 8 ft. in diameter, filled with concrete, inclined at 45° and parallel with axis of bridge. They are made up of half-inch wrought iron plates, about 2 ft. by 3 ft., the joints being parallel and square with the axis of cylinder, and connected by 3½ in. angle irons riveted around edges of plates and bolted together when in position, forming rings 2 ft. in length and breaking longitudinal joints.

At the upper end of a cylinder a connecting shaft was built, 4 ft. in diameter, extended to the surface, upon which was placed the air lock, with the lower end cut, and flanged to the required direction of cylinder. Parts of two rings were always kept in advance of a completed ring, so that the lower edges approximated a horizontal, holding out the water more readily. After they had been advanced to, and a step made into, the rock, the cylinder was partly filled with concrete composed of one part best German Portland cement, two parts bar sand and four parts broken stone. Two shoulders were then cut into the base of the abutment, and the cylinder completed by extending it up to the abutment and filling with concrete.

A double air compressor, with 10 in. steam and air cylinders, made by De Lematre & Co., N. Y., was used with the Edison system of electric light. Work was commenced October 9th, 1884, and completed February 24th, 1885.

Prof. Haupt did not wish to appear to criticise adversely the conclusions of the writer, but he felt disappointed that the paper did not contain some data, which would support the theory which led to the use of the piles in their present position. This misconception of the problem arises apparently from a failure to distinguish which of the equal and opposing forces is the action and which the reaction, or which the power and which the resistance. If the damage to the west abutment were caused by the *thrust of the iron arches*, as alleged, then its effect would be first manifested on the abutment pier and the adjoining brick arch, before reaching the extreme or land side of the second masonry arch. The writer states that this wall has been thrust *back*, whilst his measurements show that the span has been *reduced* in some places nearly half a foot, and that the reduction of span is greatest at the springing line near the head walls, and also near the ground. He admits that the main abutment-pier has *not* moved, nor has the one to the west of it, between the two masonry arches, as the eastern span of 60 ft. is not affected. The span of the second arch could only be *reduced*, therefore, by its abutment-wall moving *forward*.

Prof. Haupt believed that the defects of the bridge resulted from a slight settlement on springing of the piles under the corners of the foundation of the abutment and approach walls, thus reducing the frictional resistance of the masonry on the grillage, and permitting the excessive pressure of the earth filling, especially when saturated with water, to overcome the inertia of the masonry in these walls, and break the bond, which, in some places, was very weak, causing the large cracks in the approaches and the first arch. He suggested that the remedy should have been applied originally at this point by the introduction of screw or disc piles around the outside of the abutment, by which the unit pressure might have been reduced to any desired extent. The present tubes are being made to abut against a part of the foundation which is admittedly rigid, are placed at some 120 ft. from the weak point, and in such a direction as to oppose no resistance to this thrust.

There is nothing in the paper relative to the effect produced by the former remedies of heavy sills and ties, nor to show that they were so inefficient as to render this last device a necessity in any position.

Mr. Howard Murphy thought that these "heavy sills" should never have been built. They are, in reality, built-up, horizontal struts or columns, connecting the substructures, and were intended to relieve the main abutment of

a portion of the horizontal thrust of the west iron river arch, by conveying it to the approach abutment through the intermediate pier. That they would, if brought to firm end bearings, have increased the stability of the structure, whichever way it has a tendency to move, there is no doubt, if these were all the conditions to be considered. But the Thirtieth Street Extension of the Pennsylvania Railroad passes under one of the arches. The traffic is entirely freight. Ths heaviest engines and trains may be frequently stopped and started under the bridge, as these tracks are practically a portion of the yard. The struts were laid but a short distance under the surface. If loose, they did no good. If tight, they afforded a very convenient rigid medium for the transmission to the bridge foundations of every shock and hammer blow incident to heavy railroad traffic. The often observed effect of light machinery upon the masonry of buildings, would seem to indicate that a bridge which could stand this kind of thing without serious rupture was not such a bad bridge after all.

As to whether or not the original designs for the foundations of Chestnut Street Bridge had been faithfully carried out by the contractor, Mr. Murphy stated that any assumption of careless *supervision* of the contractors was absolutely inadmissible.

He differed with Prof. Haupt as to the easterly or riverward movement of the structure, because there seems to be no cracks or changes which *clearly* show this, and, on general principles, because a pier is not likely to move under the thrust of a short high arch against the thrust of a long, flat arch; and because a failing retaining wall is not likely to bulge, horizontally, *towards* the retained material, particularly when tied at its ends by walls running at right angles to it, and against which latter walls there is a greater thrust of arch, owing to some excess of weight, of the spandrels and parapets, over the earth-filling in the middle. Comparison with the accurate transit points, entirely external to the structure, which Prof. Haupt has located, may, however, reveal changes, in one or more directions, now indeterminable.

PROCEEDINGS OF THE ENGINEERS' CLUB OF ST. LOUIS.—ST. LOUIS, MARCH 4TH, 1885.—The Club was called to order at 8:15 P. M. by President Moore.

The Executive Committee recommended that Mr. Henry B. Wood be elected a member of the Club, being balloted for he was declared unanimously elected.

The next order of business was the reading of a paper on "Treatment of Wood for Street Pavements," by Messrs. Caldwell and Miller. It was discussed by Messrs. Constable, Johnson, Robt. Moore, H. C. Moore and Lansden. Mr. Theo. Plate, President American Wood Preserving Company being present, was called on to give his views. He expressed it at his opinion that the idea, that gum wood was a cheap wood, was a mistake, because when all heart wood was required it necessitated more work, and, consequently, greater expense in securing it has heretofore been anticipated.

Mr. Lansden exhibited a section of water-pipe from Falls River, Mass., which had lain about eighteen months in a bed of cinders, where it was submerged in tide water twice in twenty-four hours. It had disintegrated two-thirds of the way through, and leaving a substance as soft as graphite, the pitch coating of the pipe still being plainly visible both inside and out.

ENGINEERING NOTES.

CANTILEVER BRIDGE AT NIAGARA FALLS.—The preliminary study and estimate for this double-track railroad bridge was made at the request of the Central Bridge Company of Buffalo, by Mr. Schneider, in October, 1882, and he at that time concluded that the river span should be so designed as to allow it to be erected without false works, and that a hinged arch on the cantilever principle would be the proper form of construction, he having in the spring of 1882 designed the Fraser River Bridge for the Canadian Pacific Railway, where similar conditions existed, precluding the use of false works. After securing a profile of the site, the design and estimates were perfected, and a tender for the construction of the entire work submitted by the Central Bridge Company to the Niagara River Bridge Company, and after approval by the consulting engineer, Mr. Charles H. Fisher, M. Am. Soc. C. E., the contract was awarded on April 11th, 1883, to the Central Bridge Company, on condition that the structure be completed on December 1st of the same year. The contracts for portions of the work were sublet; excavations and masonry to Dawson, Simmes & Mitchell, false works to C. H. Turner, Beton foundations to John C. Goodridge, Jr., steel and iron compression members for towers to Kellog & Maurice.

Mr. Schneider was appointed, by the Niagara River Bridge Company, Chief Engineer, on April 26th. The work, both at the bridge site and the shops, was vigorously pushed, and the bridge was completed and opened for traffic on December 20th, 1883, about eight months from the commencement of the work.

The bridge is over the Niagara River, about two miles below the Falls and 300 feet above the Railroad Suspension Bridge. The bridge spans a chasm of 850 feet in width, and 210 feet in depth to the surface of the water. The river is 425 feet wide at the bridge site; the water has a velocity of 16½ miles per hour at the center of the river. The depth is supposed to be from 50 to 80 feet. The banks on both sides slope at about 45 degress from the water's edge to about 50 feet below the top of the cliff, above which they are horizontal. The sloping banks consist of a mass of large boulders and broken stone from the hard limestone layer which forms the upper stratum, mixed with earth and *debris*. This hard limestone, which has been undermined by the water acting upon it and cutting away the argillaceous rocks, has fallen in hard masses and formed a natural rip-rap, preventing further erosion. The pits for towers at the water's edge were in this loose, hard stone. No solid rock was found. It was de-

termined to prepare the bed for the masonry upon the very large boulders at the bottom of the pits by filling to a depth of about 8 feet with Beton Coignet, well rammed into all interstices on bottom and sides. The foundation area for each pair of piers is about 1,000 square feet, and the weight about 5,930,000 pounds, or 5,930 pounds per square foot. The stability of this foundation was considered by two commissions of engineers, both of which commissions expressed themselves satisfied as to to their stability. The members of these commissions were Messrs. George S. Morrison, Charles Macdonald, John A. Wilson, A. W. Stedman, and Theodore Cooper.

The masonry of the piers is limestone laid in cement. They are 38 feet high above the beton. The stones were lowered from the trestle, afterwards used for the erection of the towers and shore arms of the cantilevers. The anchorage piers are on the top of the cliffs. They are buiit on a platform of plate girders, connected by anchor bars to the shore ends of the cantilevers, thus utilizing the weight of the whole mass of masonry of the piers. Each anchorage pier weighs about 2,000,000 pounds.

The towers are 132½ feet from top of masonry to center of lower chord of cantilevers. Each tower consists of four main posts, with horizontal struts and diagonal tie-rods. Each post is formed of steel plates and angles. The horizontal struts divide the towers into five sections of nearly equal height. The posts have a batter of 1 in 8 at right angles, and of 1 in 48 parallel to the axis of the bridge. The distance between centers of posts at their base is 60 feet 7¼ inches at right angles, and 30 feet 5⅛ inches parallel to the axis of the bridge. They rest on cast-iron shoes at the bottom. The tops consist of steel castings, which support the cantilever on 7½-inch steel pins.

The structure carries a double track. It consists of two cantilevers resting on the towers, the shore ends being anchored to the anchorage piers, and the river ends connected by an intermediate span. The distance between centers of anchorage piers is 910 feet 2½ inches; length of each cantilever, 395 feet $2\frac{5}{16}$ inches; length of intermediate span, 119 feet 9⅞ inches. The moving load assumed in proportioning the structure was a train on each track, headed by two 66-ton locomotives, having 72,000 pounds on three pairs of drivers, spaced 6 feet between centers, followed by a train load of 2,000 pounds per lineal foot. The floor system is proportioned for 78-ton consolidation engines. The lateral system is proportioned to resist a wind pressure of 30 pounds per square foot on a train surface of 10 feet high, and upon the exposed surface of truss and floor system; the pressure on the train surface being considered a moving load. Strain sheets accompany the paper.

The tower posts, lower chords, center and end posts of cantilevers, pins, top-castings for towers are of steel. All the other parts are of wrought iron, except the shoes for tower posts, filling rings, washers and hand-rail posts, which are of cast iron.

Each cantilever consists of a shore arm 195 feet $2\frac{5}{16}$ inches long, one panel 25 feet over the tower and a river arm of 175 feet length. The cantilever trusses are divided by vertical posts into panels of 25 feet, with the exception of the end panel of the shore arm, which is 20 feet $2\frac{5}{16}$ inches; they have a double system of diagonals and are spaced 28 feet between centers; they are 56 feet deep over the towers, 26 feet over the last vertical post at the river end, and 21 feet over the last vertical post at the shore end.

The upper chords of the shore arm receive alternate tensile and compressive strains, loads which are applied between the anchorage and the tower produce compression, and those applied to the river arm or intermediate span produce tension. These chords are of eye-bars, with a compression member of plates and angles, double latticed, packed between the bars.

The upper chord in tower panel and the upper chord of river arm are composed entirely of eye-bars. The lower chords and inclined end posts of the cantilevers are steel compression members of plates and angles. The vertical posts over the tower supports are of steel, two plates and four angles. The intermediate vertical posts are of two channels double laced.

All the principal connections are made by steel pins 5⅝ inches, 6¾ inches and 7½ inches diameter.

The cantilevers are connected to the anchorage piers by rockers permitting horizontal movement.

The intermediate span has five panels of 24 feet.

The iron used was manufactured by Atkins Bros., of Pottstown, and Graff, Bennett & Co., of Pittsburgh. The steel was made by the Spang Iron and Steel Company, of Pittsburgh. The steel pins and castings were made by the Cambria Iron Company. All the materials were manufactured into finished members at the shops of the Central Bridge Works, at Buffalo, except the compression members for the towers, which were made at the shops of Kellogg & Maurice, at Athens, Pa.

The heads of the eye-bars were formed by die forging.

The towers were erected by means of derricks on the false works, the material being lowered from the cliffs to the floor of the false works and thence to the towers. The tower on the American side was begun August 29th and finished September 8th; that on the British side was begun September 10th and finished September 18th. The shore arms of the cantilevers were then erected on the false works, a track laid on them and the travelers for the construction of the river arms put in position. These were substantial wooden frameworks on iron wheels. The travelers were fastened by clamps to the floor-beams of the completed portion. Each traveler had two derricks connected with a hoisting engine, by means of which the materials were lifted from cars and lowered to their place in the structure. A hanging platform was suspended from the traveler.

The American shore arm was begun September 25th, completed October 15th. The Canadian shore arm was begun October 8th,

completed October 22. The American river arm was begun October 28th; the Canadian river arm was begun November 4th. The last connection was made November 22d. The first track was completed December 6th, on which day a locomotive crossed the bridge. The whole structure was completed December 19th.

The bridge was formally opened and tested in the presence of a large number of engineers on December 20th. The tests were conducted by a committee, Messrs. George S. Morison, Theodore Cooper, Charles Macdonald and Thomas Rideout. The inclemency of the weather at that date made another series of tests desirable, which were conducted by the same engineers, whose report accompanies the paper. The specifications for the bridge and the report of tests on eye-bars also accompany the paper—*Transactions of Am. Soc. C. E.*

IRON AND STEEL NOTES.

A NEW PROCESS FOR TOUGHENING STEEL.—The French Société d'Encouragement have had under prolonged examination a process, invented by M. Clemandot, for working steel. This process is described by the *Revue Industrielle* as consisting in heating the metal until it acquires a sufficient ductility, and then subjecting it to a high pressure during cooling. In this way a modification of the structure of the metal is produced, and the material acquires properties analogous to those developed by tempering. Similar processes have been tried in France, but only upon the same principle—that is to say, by operating upon the metal while yet in the state of fusion. M. Clemandot, on the contrary, takes steel already made, heats it simply to a cherry red, and submits it, by means of a hydraulic press, to pressures of from 1000 to 3000 kilos per square centimeter. After having allowed the steel to cool between the two plates of the press, it is withdrawn with all its new qualities perfectly developed, and does not require any further treatment. The result of the process is to impart to the steel a fineness of grain, a degree of hardness, and a notable accession of strength to withstand rupture. This alteration is most considerable with highly carbonated steel; and in this respect the metal is made to resemble tempered steel, without being in all points identical with it. The cause of the alteration in physical condition is ascribed to the rapid heating and no less rapid cooling of the metal. When the red-hot steel is first strongly compressed, the conversion of the mechanical energy into heat serves to raise the temperature of the entire mass, at the same time that the particles of the metal are more closely cemented together. This effect is followed by a rapid cooling, due to the contact of the plates of the hydraulic press with the surfaces of the metal. The close pressure materially increases this conducting effect of the cold metal.

RAILWAY NOTES.

THE locomotives of the German Railroad Union in 1882 consumed, among other fuels, 49,827 tons of peat. The Austro-Hungarian roads in the Union burned considerable wood—209,918 cubic metres, against 974,316 tons of lignite and 655,708 tons of coal. On the German roads 97 per cent. of the fuel used—reckoned by heating capacity—was coal; on Austro-Hungarian roads, only $50\frac{2}{3}$ per cent. The total consumed on all the Union roads was equivalent to 4,560,628 tons of coal.

ORDNANCE AND NAVAL.

THE firing of H. M. S. Sultan at the forts at Inchkeith constituted a confidential experiment. Major O'Callaghan, R.A., was appointed to attend from the department of the Director of Artillery. Sufficient, however, has appeared in the *Standard* of Thursday, August 14th, to give a general idea of what occurred. Although the guns of the works were mounted *en barbette*, very little effect was produced at first by the machine guns at 1000 and 1500 yards, or by the heavy guns at from 1500 to 3500 yards range. Eventually, by a great expenditure of ammunition, the machine guns did considerable execution among the dummy detachments, but not so much as might have been expected. The heavy 12-inch guns with shrapnel, on the other hand, were found so destructive that the firing was discontinued without trying the power of common shell. As the *Standard* observes, in all this there was nothing revolutionary to our present system of organizing armaments. On the other hand, it rather indicated that we ought not to withdraw our confidence from our regular armaments of heavy guns and shrapnel, and depend on new weapons without abundant proof, for the work of firing at the *personnel* of an enemy.

BOOK NOTICES

PUBLICATIONS RECEIVED.

SIXTEENTH annual report of the (Mass.) Board of Railroad Commissioners, Boston: Wright & Potter.

Fifteenth Annual Report of the New Bedford Water Board. New Bedford: Mercury Pub. Co.

Professional Papers of the Corps of Royal Engineers. Vol. IX. London: Royal Engineers Institute.

Selected Papers of the Institution of Civil Engineers: The Steam Engine. By Edward Alfred Cowper, M. Inst. C. E. Independent Engine Tests. By John George Mair, M. Inst. C. E. Abstracts from Foreign Transactions and Journals.

Report on Gedney's Channel Congressional Document.

Cassell's Magazine of Art. New York: Cassell & Company.

Signal Service Notes. No. XIII. The Relation between Northers and Magnetic Disturbances at Havana, Cuba. By G. E. Curtis, Serg't.

No. XVII. A First Report upon Observations of Atmospheric Electricity at Baltimore. By Park Morrill. Washington: Signal Offices.

Reports of the Examiners of the Electrical Exhibition of 1884:

Section No. XIX. Electric Telegraphs.
No. XXIV. Electro Dental Apparatus.
No. XXVII. Applications of Electricity to Warfare.

PRINCIPLES, THEORY AND PRACTICE OF MATHEMATICAL COMMENSURATION. By CHARLES DE MEDIA, Ph. D. Chicago: A M. Flanagan.

THE FALLACY OF THE PRESENT THEORY OF SOUND. By HENRY A. MOTT, JR., Ph. D. New York: Printed for the author by John Wiley & Sons.

These two publications may, for the purpose of a brief review, be considered together, for the reason that they are alike in being late contributions to popular ignorance, and alike in a pernicious tendency to lead the unlearned to reject scientific teachings and to scorn logical methods of deduction.

Both writers belong to the class termed by De Morgan "Paradoxists." Both urgently demand a revision of theories, long since accepted as the best presented to account for observed facts.

The difficulty experienced by the first of these authors seems to lie in the multiplication table. After falling out with this useful and generally credited aid to computation, the attainment, by an original method, of the final object of his research, is direct and easy. This is only the squaring of the circle.

Of course he differs from all the other circle squarers.

A single specimen of the author's unique method of computation is afforded on page 17, where the side of a square being given at $8\frac{1}{2}$, the diagonal is found to be *exactly* 12. Readers who cannot accept this conclusion had better stop at this point in the book.

The difficulty experienced by the author of the second book above-mentioned is not very unlike that encountered by the first, but the sentiment that prompted the preparation of the treatise is not quite the same.

In the first, the author has a theory to promulgate. The second book is only a tirade of fault-finding. The author discourses flippantly of the "mistake of Helmholtz," "the childish experiment" of Tyndall, etc., and offers in refutation of the theories of Tyndall, Lord Rayleigh, Mayer, Rood, Blaserna and Sir William Thomson, the opinions of Dr. Wilford Hall and Professor Carter!

A brief mention of the style of argument is all we have space for here, and is more than we should afford were it not for the fact that the author was permitted to deliver the treatise as a lecture before the New York Academy of Sciences.

Here are the examples: It is claimed that inasmuch as the real average velocity of the prong of a tuning fork is slow; that is, taking into account the distance through which it travels in a given time—the vibrations communicated to the air cannot be rapid enough to produce sound; "the stops and starts cannot produce them."

In another place under the heading of "The Physical Strength of the Locust," the author argues that inasmuch as the stridulations of a locust can be heard a mile, while the insect weighs less than a quarter of a pennyweight, that the strength of this insect must be sufficient to move four cubic miles of air as a mass. This is followed by a remarkable suppositious case, viz., if the above-mentioned insect (whose estimated weight by the way can only be that of a locust who has been for a long time "off his feed") were placed in the center of a cubic mile of iron, his stridulations would (admitting the wave theory) be capable of moving five thousand million tons. This, the author infers, must be taken by modern scientists (excepting Dr. Mott, Dr. Hall and Prof. Carter) to be a measure of the physical strength of the locust.

Leaving this last experiment out of the question, as rather unlikely to be verified, it is apparent from the statement regarding the other. that the author has very ill-defined ideas regarding molecular motion, and none at all of mechanical work.

The author declares that the results obtained in acoustic experiments are, upon the wave theory, incredible. We do not doubt they are to him. But this fact has no relation to acoustics.

INORGANIC CHEMISTRY. By EDWARD FRANKLIN, LL.D., and FRANCIS R. JAPP, Ph. D. London: J. & A. Churchill. Price $8.40.

As this is the latest treatise upon Inorganic Chemistry, it is presumably the best presentation of lately discovered facts. We judge from such examination as could be made in a limited time that the most important improvement over other late works will be found in the first 130 pages, which contain a good compend of the Principles of Chemical Philosophy. A chapter on Thermo-Chemistry is especially valuable.

Throughout the remainder of the 800 pages, the principles and facts of Elementary Chemistry are presented in a manner at once compact, clear, and as full as the ordinary student can desire in an ordinary book of reference.

A TEXT-BOOK OF THE METHOD OF LEAST SQUARES. By MANSFIELD MERRIMAN. New York: John Wiley & Sons. Price $2.00.

This is to replace the edition long since exhausted of The Elements of the Method of Least Squares by the same author—written in 1877. That the book was wanted was made manifest by its wide adoption. We notice with satisfaction that it is quoted as a standard by so careful an engineer as Petrie in his Pyramids and Temples of Gizeh.

The new book is offered as an improvement on the former one, inasmuch as numerous applications are made of principles to the different classes of observations.

CASSELL'S FAMILY MAGAZINE for April, contains among other timely and useful articles: How American Bread is Made, the Road to the Giant's Causeway, Work in the Garden, Wild Birds in London. The illustrations are exceedingly numerous.

THE QUIVER, an Illustrated Magazine for Sunday and General Reading. New York: Cassell & Company.

Each number contains 128 pages of reading matter, mostly of an instructive character.

UNITED STATES GEOLOGICAL SURVEY: GEOLOGY OF THE COMSTOCK LODE AND THE WASHOE DISTRICT. By GEORGE F. BECKER. Washington: Government Printing Office.

The volume of text treats by chapers of—The Comstock Mines, Previous investigations of the Lode, Lithology, the Structural Results of Faulting, the Occurrence and Succession of Rocks, Chemistry, Heat Phenomena of the Lode, the Lode, on the Thermal Effect of the Action of Aqueous Vapor on Feldspathic Rocks, on the Electrical Activity of Ore Bodies, Summary.

Some fine lithographic plates embellish the text.

The Atlas to accompany the above descriptive text contains 21 large plates, illustrating the geography, the geology, and the mining claims of the district; the whole beautifully printed in color.

This famous lode has exhibited many points of interest. It yielded in twenty-one years ore to the value of three hundred and six millions of dollars, forty-four per cent. of which was gold.

It was the deepest mine in America, extending to a depth of three thousand feet below the surface. The united length of its galleries is 185 miles. And finally, the unusual heat at the lower depths has afforded an interesting problem to geologists.

Everything relating to the physics, geology and lithology of the district is fully discussed and elegantly illustrated.

THE WAVE OF TRANSLATION IN THE OCEANS OF WATER, AIR AND ETHER. By JOHN SCOTT RUSSELL, F. R. S. S. Price $5.00.

This work is divided into three parts as follows: Part I. The Wave of Translation. Part II. The Wave of Translation and the work it does as the Carrier Wave of Sound. Part III. On the Great Ocean of Ether and its Relation to Matter.

An appendix containing a Report on Waves to the British Association, presented by the author in 1842–43, forms quite an important portion of the work.

The work is illustrated by ten photo-lithographs of the plates made to accompany the "Report" about fifty years ago. As might be inferred, they are wanting in clearness. The typography of the work is excellent.

SPON'S MECHANIC'S OWN BOOK. New York: E. & F. N. Spon. Price $2.50.

This book contains a collection of useful receipts designed to be serviceable to all classes of artisans. The descriptions of processes seem to be clear and full, and it is difficult to conceive of a trade or handicraft to which this book does not in some part relate.

The illustrations are numerous and good.

FOURTH ANNUAL REPORT OF THE STATE MINERALOGISTS OF CALIFORNIA. By HENRY G. HANKS. Sacramento: James J. Ayers.

This volume includes two reports as follows: California: Information General and Statistical of the Resources and Industries of the State. By Henry Degroot

The minerals of California, as far as known, alphabetically arranged.

The mention of the mineral is supplemented in many instances by an interesting account of the substance, including its natural history and geographical distribution.

Mineralogists will find this report valuable.

THIRD ANNUAL REPORT OF THE UNITED STATES GEOLOGICAL SURVEY. By J. W. POWELL. Washington: Gov't Printing Office.

This volume contains after the administrative reports the following papers:

Birds with Teeth. By Prof. O. C. Marsh.

The Copper-Bearing Rocks of Lake Superior. By Roland D. Irving.

Sketch of the Geological History of Lake Lahontan. By Israel C. Russell.

Abstract of the Report on the Geology of the Eureka District. By Arnold Hague.

Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch. By. Thomas C. Chamberlain.

A Review of the Non-Marine Fossil Mollusca of North America. By C. A. White, M. D.

The illustrations which embellish the text, as well as the maps, especially the latter, are of a superior quality.

MISCELLANEOUS.

TECHNOLOGICAL SCHOOL OF THE BALTIMORE & OHIO RAILROAD COMPANY.—The inauguration of a Baltimore and Ohio Technological School for the promotion of a higher course of instruction for the apprentices of this service than now pursued, with headquarters at Mt. Clare, Baltimore, and conducted under the superintendence of a Board of seven Directors, appointed annually by the President of this company, is announced:

Messrs. John K. Cowen, E. J. D. Cross, Dr. Charles M. Cresson, Andrew Anderson, Dr. W. T. Barnard, Bradford Dunham and Charles Selden, are hereby appointed such Directors for the calendar year 1885.

The course and method of instruction in its several departments, and the operations of the Technological School, shall be governed by regulations prescribed by its Board of Directors.

The examinations prescribed in the course of the Technological School will be very thorough, and will require from the apprentice a close and persevering attention to study, without evasion or slighting of any part of the course, as no relaxation of any kind can be made by the Board of Examiners; and, as the company will hereafter endeavor to advance the graduates of the Technological School to positions of responsibility and trust in its service, only those who demonstrate willingness and ability to qualify themselves for advancement will be retained.

The General Manager will convene a Board of Examiners consisting jointly of two Medical Examiners of the Relief Association and three Instructors of the Technological School, whose duty it shall be to examine and classify all apprentices now in service, in accordance with the standard of qualifications prescribed in his General Order on the subject. This Board will visit each station where apprentices are employed and finally report, in writing, to the General Manager, the result of their labors.